# BIOLOGICAL CLOCKS AND SHIFT WORK SCHEDULING

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## HEARINGS

BEFORE THE

SUBCOMMITTEE ON
INVESTIGATIONS AND OVERSIGHT

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

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# BIOLOGICAL CLOCKS AND SHIFT WORK SCHEDULING

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## WEDNESDAY, MARCH 23, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Investigations and Oversight,
*Washington, D.C.*

The subcommittee met, pursuant to call, at 10:30 a.m., in room 2154, Rayburn House Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

Mr. Gore. The subcommittee will come to order.

I would like to welcome all of our guests and our witnesses.

Many who travel great distances are familiar with the phenomenon of jet lag. Many feel tired, find difficulty concentrating, and feel out of phase with the activities going on around them. For infrequent travelers, jet lag may be liitle more than a nuisance, but for an estimated 25 million U.S. workers whose job shifts change weekly, "occupational jet lag" results in a variety of problems which hold consequences for labor, management, and the general public.

Workers know that shift changes can result in insomnia, fatigue, digestive disorders, mental confusion, memory lapses, irritability, and problems in their family relationships. Management knows that shift workers are subject to greater turnover, greater absenteeism, illness, work accidents, and inefficiency than their counterparts who do not work on constantly changing shifts. The general public can suffer health and safety consequences if policemen, firemen, hospital personnel, air traffic controllers, and nuclear power plant operators, and the like are not functioning at their best. The fact that the accident at Three Mile Island occurred at 4 a.m., for example, following numerous shift rotations on a regular basis, could be related to problems of worker performance during the crisis.

Nearly a quarter of our population works on some form of rotating schedule, reflecting the accelerating pace of our society; in addition to the traditional night work places—hospitals, police and fire departments, morning newspapers, and some factories—more and more restaurants, supermarkets, drugstores, and fast food outlets are staying open around the clock.

To management has fallen the responsibility for scheduling work to insure that no employee is destined to spend all of his daylight life sleeping merely because he is assigned to a night shift. So management has devised systems of shift rotation. In preparing for these hearings, I came to realize that management would have welcomed assistance in scheduling shift rotations long ago, but did not know where to go for information. At the same time, I have learned that sleep researchers, wanting to take their findings out of the laboratory and put them to practical use, have been searching for managers who would welcome shift scheduling experiments in their companies.

Left to devise its own methods, however, management has tended to schedule shift rotations to suit its own convenience or simply to follow traditional patterns. As a result, there are no consistent patterns in this country for shift rotations. For example, Boston police sometimes have their schedules changed daily. On U.S. submarines, enlisted men work regularly 6 hours on, 12 hours off every day. The only exception to the tradition of management determining shift rotation patterns seems to come when unions bargain for this right. Since workers may be only vaguely aware of the relationship between work schedules and their biological clocks—as most of us are only vaguely aware of that relationship—union preferences in shift rotation have been motivated primarily by a desire to accommodate leisure activities.

Now things are changing. A new chapter in management/researcher/labor cooperation began when Mr. Preston Richey, factory production manager, got together with Dr. Charles Czeisler of Harvard and his colleagues to help figure out a new schedule of work rotation that would lessen employee dissatisfaction at the Great Salt Lake Chemicals and Minerals Corp. in Ogden, Utah. Since the new, scientifically designed schedule for shift rotation has gone into effect, worker satisfaction at the plant has increased, health complaints have decreased, and productivity has risen substantially. We will hear today from Dr. Czeisler and from management and workers at Great Salt Lake.

Research on the body's biological rhythms is also being used in programs designed to protect public health and safety, as well as to improve its economy. The Defense Department has had to look at biological rhythm research in establishing the rapid deployment force. NASA has used such research in designing space travel tasks, and both the Nuclear Regulatory Commission and the Federal Aviation Administration, who will be testifying tomorrow, are seeking to utilize such research as they look toward making better regulatory decisions.

I look forward today to hearing more about this fascinating and important area of research.

I would now like to recognize the ranking minority member of the subcommittee, Mr. Skeen.

Mr. **Skeen**. Thank you, Mr. Chairman.

In the introductory statement that you made, I thought maybe you were describing those of us in Congress, who would make apt research projects for some of this kind of work—especially when you make an overnight trip to Tennessee and back.

The application of research on circadian rhythm, the so-called biological clocks, to shift work scheduling is an outstanding example of how basic scientific research can be applied to the everyday lives of the average American. In this case, improvements can be realized by one out of four in the Nation's work force.

For most Americans, our lives revolve around our work and our play. The results of scientific and technological research have been at the forefront of improved conditions in the workplace and in our overall quality of life. Few of these improvements, however, carry such an all-pervasive nature as the painless application of circadian rhythm research to the design of shift work scheduling.

From my understanding of the current job research results—and I plan to learn a great deal more today—the benefits accruing from a few simple changes in how alternative shifts are scheduled can result in greater worker satisfaction, health, and performance on and off the job. Both the employer and the employee benefit as improvements in the worker's ability to sleep translate into a more alert and productive labor force with less mental and physical fatigue. There are also fewer physical problems, such as digestive disorders—for some of us that is a very large disorder—common among shift workers. Significant improvements in family and social life result when lessons from the body's natural rhythms are taken into consideration.

The results, in my opinion, are very impressive. Workers are happier and healthier. Their family and social lives improve, as their performance and safety on the job improve. The employer has a more productive worker with fewer physical problems, less absenteeism and reduced turnover. Everybody wins in this case, which is why this subcommittee is so pleased to have these hearings.

I am looking forward to today's and tomorrow's hearings, especially because of the distinguished list of witnesses who have honored us with their presence here today. I want to join with the chairman in thanking them for assisting this subcommittee and bringing this important issue before the Congress.

Thank you, Mr. Chairman.

Mr. GORE. Thank you.

I would like to now call our first panel up to the witness table. Mr. Gordon Thompson; Mr. Kerry Day, police officer from Prince George's County Police Department; Jeanne M. Jones, registered nurse with the American Nurses Association and vice president for Nursing Services with the Cumberland Medical Center in Crossville, Tenn.; Captain Richard Stone, airline pilot, representing the Airline Pilots Association here in Washington; and Mr. Frank Pollack, nuclear reactor operator with Commonwealth Edison Quad Cities Plant in Bettendorf, Iowa.

Our procedure is to ask all of the witnesses on the panel to make their statements, and then we will have questions after the panel has concluded.

Our first witness is Gordon Thompson, an employee with Bridgestone Tire Co. He lives at route 2, Carthage, Tenn., better known as Elmwood. For the record let me say that Gordon and I grew up together and we are close friends. This hearing really originated several years ago when he and I were having a conversation about the subject. I went and looked at the scientific evidence and found out that he was right. I asked him to come up and lead off this hearing. We are delighted to have you.

[The biographical sketch of Mr. Thompson follows:]

### GORDON THOMPSON

My name is Gordon Thompson. I was born May 3, 1945, in Carthage, Tennessee, where I still reside with my wife of eighteen years and my fourteen year old son.

After graduating from Smith County High School in 1963, I was employed as a press operator at Precision Rubber Company in Lebanon, Tennessee, where I worked for one (1) year.

In 1964, I was employed by Western Auto Company in Nashville, Tennessee as a dock worker until 1973. During this time at Western Auto, I also served six (6) years in the Tennessee Army National Guard.

In 1973, I was employed by Firestone Tire & Rubber Company in Nashville, Tennessee, where I have been a tire builder for the past ten (10) years.

## STATEMENTS OF GORDON THOMPSON, EMPLOYEE, BRIDGESTONE TIRE CO., CARTHAGE, TENN.; KERRY DAY, POLICE OFFICER, PRINCE GEORGES COUNTY POLICE DEPARTMENT, COLLEGE PARK, MD.; JEANNE M. JONES, REGISTERED NURSE, AMERICAN NURSES ASSOCIATION, AND VICE PRESIDENT FOR NURSING SERVICES, CUMBERLAND MEDICAL CENTER, CROSSVILLE, TENN.; CAPTAIN RICHARD STONE, AIRLINE PILOT, AIR LINE PILOTS ASSOCIATION, WASHINGTON, D.C.; AND FRANK POLLACK, NUCLEAR REACTOR OPERATOR, COMMONWEALTH EDISON QUAD CITIES PLANT, BETTENDORF, IOWA

Mr. THOMPSON. Thank you, Al.

When I was employed in 1973 by Firestone Tire and Rubber Co., the only shift I could obtain at that time was a 7-day rotating shift. I have enclosed a graph of the shift that I worked.

The shift consisted of 7 nights, 12 to 8, off 2 days; working 7 days, 4 to 12, off 1 day; work 7 days, 8 to 4, off 4 days. I worked this rotating shift for approximately 2½ years.

When I first started working this shift, it did not take long before it started affecting me mentally and physically. Most of the jobs in the plant are very physically demanding jobs. Therefore, rest became the No. 1 priority. At first, I had problems sleeping, and the rest I got did very little good. I have actually seen workers go to sleep standing up while operating a piece of equipment. Even driving home was a task in itself, particularly when I worked the midnight shift. Several times I caught myself dozing and running off the side of the highway.

After 2 years of working this rotating shift, I started taking sleeping pills to acquire sufficient rest. Then it started affecting my eating habits, and my sense of taste gradually diminished. I also had problems with my stomach and digestive system. It was difficult to decide what type of food to eat, especially on the 12 to 8 shift.

After 1 year of rotating, I started having family problems because I had hardly any time off to be with them. The days that I was off, I had to rest so I could hold out to work for the next 7 days. My whole world seemed to revolve around my work. Before I started rotating work, I used to hunt, fish, and enjoy sport activities—that all stopped. I lost interest in everything that I had previously enjoyed. Not only did it affect me, but everyone I worked with.

I could see such a difference in my friends at work. People would go to the break area and no one would talk to each other; and if they did, it was something negative about their work. The working relationship with the supervision was also very poor. It seemed like it was a constant battle between production workers and the management.

The divorce rate among the employees was very high. It seemed as though every week I would hear of someone getting a divorce or going to get one. After working like this for a while, I thought I would get accustomed to working under these conditions. But the longer I stayed, the worse it became. After 3 years, the employees' attitudes, absenteeism, work-related injuries and low productivity became so bad that the company decided to abolish the 7-day rotating shift. Not long after the shift was changed, it was like working in a different plant.

From my own personal experience with all the stress, physical and mental abuse, if I had to go back to the 7-day rotating shift tomorrow, tomorrow would be my last day to work.

[The prepared statement of Mr. Thompson follows:]

TESTIMONY TO BE PRESENTED BY GORDON THOMPSON BEFORE THE SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT:

When I was employed in 1973 by Firestone Tire & Rubber Company, the only shift I could obtain at that time was a seven day rotating shift. I have enclosed a graph of the shift that I worked. (See Attachment - A)

The shift consisted of working seven nights (12-8), off two days, working seven days (4-12), off one day, work seven days (8-4), off four days. I worked this rotating shift for approximately 2 1/2 years.

When I first started working this shift, it did not take long before it started affecting me mentally and physically. Most of the jobs in the plant are very physically demanding jobs; therefore, rest became the number one priority. At first I had problems sleeping and the rest that I got did very little good. Working under these conditions was very dangerous. I have actually seen workers go to sleep standing up while operating a piece of equipment. Even driving home was a task within itself, particularly when I worked the midnight shift; several times I caught myself dozing and running off the side of the highway.

After two years of working this rotating shift, I started taking sleeping pills to acquire sufficient rest. Then it started to affect my eating habits; my sense of taste gradually diminished. I also had problems with my stomach and digestive system. It was very difficult to decide what type of food to eat, especially on the 12-8 shift.

After a year of rotating, I started having family problems because I had hardly any time off to be with them. The days that I was off I had to rest so I could hold out to work for the next seven days. My whole world seemed to revolve around my work. Before I started rotating work, I used to hunt, fish, and enjoy sport activities; that all stopped. I lost interest in everything that I had previously enjoyed. Not only did it affect me, but everyone I worked with.

I could see such a difference in my friends at work. People would go to the break area and no one would talk to each other; and if they did, it was something negative about their work. The working relationship with the supervision was also very poor. It seemed like it was a constant battle between production workers and the management.

The divorce rate among the employees became very high. It seemed as though every week I would hear of someone getting a divorce or going to get one. After working like this for a while, I thought I would get accustomed to working under these conditions, but the longer I stayed, the worse it became. After three years, the employee's attitude, absenteeism, work related injuries and low productivity became so bad, the company decided to abolish the seven day rotating shift. Not long after the shift was changed, it was like working in a different plant.

From my own personal experience with all the stress, physical and mental abuse, if I had to go back to the seven day rotating shift tomorrow, tomorrow would be my last day to work.

ATTACHMENT - A

| Sun. | Mon. | Tues. | Wed. | Thurs. | Fri. | Sat. |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4<br>12-8 Shift<br>work | 5<br>12-8 Shift<br>work | 6<br>12-8 Shift<br>work | 7<br>12-8 Shift<br>work |
| 8<br>12-8 Shift<br>work | 9<br>12-8 Shift<br>work | 10<br>12-8 Shift<br>work | 11<br>off | 12<br>off | 13<br>4-12 Shift<br>work | 14<br>4-12 Shift<br>work |
| 15<br>4-12 Shift<br>work | 16<br>4-12 Shift<br>work | 17<br>4-12 Shift<br>work | 18<br>4-12 Shift<br>work | 19<br>4-12 Shift<br>work | 20<br>off | 21<br>8-4 Shift<br>work |
| 22<br>8-4 Shift<br>work | 23<br>8-4 Shift<br>work | 24<br>8-4 Shift<br>work | 25<br>8-4 Shift<br>work | 26<br>8-4 Shift<br>work | 27<br>8-4 Shift<br>work | 28<br>off |
| 29<br>off | 30<br>off | 31<br>off | | | | |

Mr. **Gore**. Thank you very much.

You have attached to your testimony, I see, a copy of the schedule that you used to work.

Mr. **Thompson**. Yes, sir.

Mr. **Gore**. We will come back for questions.

We would like to hear now from Mr. Kerry Day, a police officer with the Prince Georges County Police Department in College Park, Md.

Welcome, Mr. Day. Please proceed.

Mr. **Day**. Thank you.

As you mentioned, I am a Prince George's County police officer. I am very much a typical street police officer. I am not an administrator or a detective or anything, I am a uniformed officer that the public is likely to encounter in emergency situations.

Let me just begin by saying that I have also worked the same indentical shift that Mr. Thompson has described, and it is very brutal. I agree with his statements completely.

Currently, I am on a two-shift program where I work 1 week of day work, in a normal routine, and then 1 week of evenings, beginning at 3 in the afternoon and ending at 11 at night. This is a vastly superior shift to the one that I previously worked for approximately 8 years, which involved going through three shifts, the day work, the evening, and then the midnight shift, and making that rotation on a weekly basis. I have also worked that type of arrangement on a monthly rotation system, which I consider to be vastly superior. But the weekly rotation tends to be too quick and you never really have time to adjust your sleeping and eating patterns.

My manner of adjusting to that was to change from a 24-hour day system to a 25- or 26-day system, where my body clock actually changed the length of its day. Whereas with most people, the amount of time they spend sleeping and awake will total 24 hours. Mine will total about 25 or 26. I would accomplish this by staying awake each day about an hour or an hour and a half longer than I had the day before. In that fashion, I was able to keep up with the rotations so that I was usually alert at the beginning of my waking day when I went to work.

This particular type of lifestyle has created certain problems, however. Some of them are very personal and domestic in nature—such things as a strained spousal relationship, and certain psychological things that are subtle to me, such as vague sense of time disorientation and a sense of being different than other people. They are not really serious problems, but are sometimes disquieting and can lead to some degree of frustration.

There are several other problems, though, that are not so personal nature, and are rather public because of the job that I have in that they affect public safety, I believe. One of the problems is an increase in fatigue and anxiety. As a police officer, this is something that I think is perhaps dangerous.

The fatigue and anxiety I don't think comes about simply because I am working shift work or because I am changing my hours. But it seems to be most exaggerated by the fact that the normal world places demands upon me which caused me to have to disrupt my normal routine. Examples of this would be off-duty court appearances. If I have adjusted myself into a schedule of rotating where, on this particular day, I should be sleeping, let's say, from 4 in the morning until 1 o'clock in the afternoon, and I suddenly find that I have an off-duty court appearance at 8:30 in the morning, I am going to get 3 hours of sleep. That is the kind of situation that would disrupt me from my pattern, and it may take me a week or two to get back into it. If I have very many court appearances or very many family considerations that will interfere with maintaining this pattern, I will run into problems with my sleep.

Some of the results of these disruptions, as far as public safety is concerned, are that I frequently will have no energy while on patrol. If I have no energy, I am not going to go out there and try to find things that are going wrong. I am going to put my uniform on, get in my car, and go out on the street. I will be in service and answer the radio if they give me a call, but I am not going to aggressively patrol to try to find things that are going wrong. I am not to take a ride down that alley because, first of all, I am simply too tired to drive the car.

The second problem will be that I am less alert and probably more prone to being personally injured if somebody wishes to do that, and perhaps less capable of preventing injury to some member of the public who I should really protect.

The third thing is that, in driving that patrol car for 8 hours, I am really a hazard to other drivers if I have had insufficient sleep. Frequently, what we will do, many of us in this situation, will simply be to park the police car and not drive any more than we have to.

There is also an attendant desire to produce less, because the more you produce in terms of arrests and things of that nature, the more disruptions you will have, the more court time that you have to take care of, the more administrative functions that will interfere with your maintaining your shift work pattern.

Mr. **Gore**. Let me interrupt you there to add emphasis to the comments you are making.

We did a telephone survey of police departments around the country and found that half used precisely this shift rotation on a weekly basis, rotating between three shifts. So the experiences that you are describing are shared by many, many thousands of police officers all across the United States.

Excuse me for interrupting. Go ahead.

Mr. **Day**. Thank you.

Some other problems with the shift work is that it is very difficult to maintain an exercise program. I think that in police work, this is very important, because our job requires occasionally that we have explosive power and intense stamina. Usually the work is very sedentary in nature but, occasionally, a few times a month, we may have to engage in a fight or have to run or chase somebody to make an apprehension. At these points in time, we have to be not only alert and well rested, but we should be physically fit, too. It is very difficult when you are constantly changing your eating and sleeping patters to maintain any kind of routine as far as physical exercise is concerned.

Our health probably deteriorates. In fact, policemen, generally, are in less suitable condition for their job than the average population, and certainly less physically fit than the general criminal population. If you go to a prison, you find that the inmates are in much better condition than we in the general police force probably are. A lot of this problem is that fact that we have these shifts. It is very difficult to get into an exercise program. I have tried them in the past and have maintained them for as long as 3 months, but something always interferes and gets me off track. It is really difficult to go back to it.

In November 1982, I was changed off of the three-shift program and put into a different job where I now work two shifts. I have found that that has reduced my anxiety, reduced certain frustrations and such, but I have also found that there is an attendent problem with going back to this more normal sort of approach. My body for 8 years operated on this 25-hour-a-day clock and, now that I no longer have to work midnights, my body wants to continue to operate on a 25-hour clock.

What is happening is when I get off of the evening shift, I am still wanting to lengthen my days, so I am staying up all night preparing, as my body would expect, to go to midnights the following week, but I am having to revert back to day work. The problem I am experiencing is that I am not able to get back into a day work pattern.

An example would be this past week when I worked evenings. On the weekend, I was staying up very late in the evening, going to bed shortly before dawn, which would have been the pattern had I been in the three-shift routine. However, on Monday morning, just about the time I was preparing to go to bed, I was having to get ready to go to work. Having been up about 20 hours, I now had to commence an 8-hour tour of duty. To say the least, when I finished that tour on Monday, I was extremely tired. On Monday, I handled three burglary investigations, and I think that the quality of those investigations was adequate, but I know from personal experience it was not as high a degree of quality as I would have expected of myself if I had been well rested. The energy simply wasn't there to really put more into it than I actually had to.

Finally, I would like to say that, beyond just the aspects of this problem as it impacts on public safety, there is also a financial aspect. As our health deteriorates, so, too, do the incidents or retirement going to go up and it is going to cause a significant drain, especially on local police departments where they have to retire men because of heart attacks, alcohol, or other kinds of mental problems. So the situation as far as police work is a significant problem. There is a lot of dissension, actually, within our industry about what the best approach to solving the problem is.

Thank you very much.

[The prepared statement of Mr. Day follows:]

## STATEMENT OF KERRY DAY

I have worked a variety of rotating shift plans since 1972 and my personal experiences have lead me to conclude that rotating shifts pose threats to the physical and psychological well-being of at least some of the workers who work those shifts.

I began work for the Baltimore City Police in 1971 and for the first year I alternated between a normal daywork shift and an evening shift which ended by 11 o'clock each night. Rotation from one shift to another occurred monthly and I had no problem adjusting to the routine. In early 1973 I was assigned to a three-shift plan however, rotating among the three standard shifts (7 am to 3 pm, 3 pm to 11 pm, and 11 pm to 7 am) on a monthly basis. I was young, intensely interested in my new career, and I found that the month-long shifts were not too disruptive. It usually took about a week to adjust to midnight work, after which the remaining three weeks of night work was manageable.

In 1974 I transferred to the PG County Police and encountered a shift plan in which I again rotated between the three standard shifts, except that the shifts now rotated weekly. I immediately found this to be more tiring and more difficult than Baltimore's monthly rotation system because it required constant changes in eating and sleeping habits without ever adjusting to any of them. Despite these negative aspects however, I managed reasonably well for a few years. Again, I was young, involved in a new job, and possessed much greater mental and physical stamina than I have possessed in more recent years.

As time passed I became more affected by these weekly rotations and I now consider them to be the single-most distasteful aspect of my career, greater even than the frustration of seeing justice sometimes denied, of witnessing various cases of human suffering, and the very real personal danger my job involves. In the 8 years I worked weekly rotations I noticed a substantial increase in my levels of anxiety and fatigue, and my domestic life has been marked by numerous disputes centering solely around the unusual hours I've worked. Specifica-ly I have encountered the following problems:

1. Strained spousal relationship - My wife is from England and, especially during the early years of our marraige, was extremely dependent upon me for companionship (she had emigrated to marry me and left all of her friends and family behind). She initially was very resentful of my constantly changing sleeping patterns and often complained bitterly about a lack of routine and the fact that I should sleep with her at night and spend my days off with her, rather than the other way around. Eventually she adjusted to my unusual lifestyle regarding time, but we both agree that the fewer hours we've had to share and the arguments over shift work have robbed us of a closeness we might otherwise have had.

2. Fatigue and Anxiety - During the past three to four years I have noticed an increase in these problems which, while I'm unable to say definitely resulted from rotating shifts, is nevertheless something which I feel has at the least been aggravated by the shift work.

3. A Vague Sense of Time Disorientation - This is a subtle and elusive problem but one which I occasionally feel very strongly. An example of this disorientation might involve a friend asking whether I'd like to go to a ballgame on Wednesday night three weeks hence. I would be unable to give an immediate answer, needing first to make mathematical calculations or pull out a calender to determine whether I'm working, or sleeping, or free for liesure activities. This lack of stability in my schedule is more a nuisance than a serious problem, but it can be disquieting and frustrating at times. It is as if, in an abstract way, I am missing a needed form of security.

4. A Sense of Being Different - This too is a subtle feeling, but I am acutely aware that I am in a special category regarding my relationships with others. I am aware that family and friends frequently make special considerations and go to great lengths sometimes in order to include me in certain social functions, trips, etc. Further, I realize that I am left out of other events because of my unusual work hours and must disappoint friends or family when I miss the functions. I even feel a quasi-guilt over being such a problem. Also I am aware that some people do not really understand the problems peculiar to my shifts and that they regard me as "strange" because of unusual habits and aspects of lifestyle which are necessitated by my shifts.

5. Eating and Sleeping Patterns are constantly changing - when working the 3-shift weekly rotation I tried to adjust by changing from a 24 hour clock to about a 25 hour body-clock. As I rotated through a cycle meals became a catch-as- you-can situation, and there was no such thing as "breakfast" or "lunch." A meal was simply whatever was available.

The "normal" world also placed demands upon me which interfered with my ability to adjust sleeping patterns to fit my shifts. Such things as off-duty court appearances, babysitting responsibilities, doctor's appointments, etc., sometimes occurred during hours I would normally be sleeping, and since the rest of the world won't change to suit me, I had to change to suit them. These conflicts often result in situations where I am forced to go 24 to 36 hours without sleeping, and the fatigue and loss of alertness and reflexes which subsequently occurs has been a source of concern to me, considering the life-and-death nature of police work.

6. Difficulty in Maintaining an Exercise Program - Because of the constantly changing hours and the unpredictability of other factors (court, family responsibilities, etc.) it is very difficult to maintain an exercise routine for any sustained period of time. This may be a serious problem, given the sporadic need for explosive power and stamina which policemen experience in performing their duties, and considering the sedentary nature of the work and its high levels of stress.

The above list of problems is by no means exclusive; there are other disadvantages, such as my children's confusion over whether Daddy's coming or going, which also apply.

In mid-November 1982 I was removed from a three-shift rotation and placed back into a two-shift plan similar to the one I worked as a rookie officer in 1972 (I now work a week of daywork and a week of evenings, etc.). I would normally consider that a superior shift plan to the 3-shift rotation, but I've noticed that during the past few months I've had difficulty readjusting to life without midnights shifts. It seems that my body has not yet grasped the fact that I've changed schedules, and it resents abandoning the 25-hour system it has known for the past 8 years. Despite this, I have noticed an easing of anxiety and I have a more positive outlook since the change occurred. I am hopeful that my body will eventually adjust to sleeping every night and that the change will prove to be beneficial.

I wish to point out that, through conversations with some co-workers, I have concluded that some people prefer rotating shifts and will perhaps never suffer physical or psychological difficulties from working them. Many others however, including myself, suffer significant disruptions and believe our health is adversely affected. As in my case, these problems may not become evident to the affected worker until several years have passed and he/she has become firmly established in a career requiring such shift work. Further, the damage done by rotating shifts (such as becoming "locked into" a hazardous lifestyle) may already have occurred by the time the worker recognizes the hazards.

Mr. **Gore**. Thank you very much.

We will come back for questions.

I would like to call now on Jeanne M. Jones, a registered nurse representing the American Nurses Association. She is vice president for Nursing Services at Cumberland Medical Center in Crossville, Tenn., which I had the privilege of representing until the district lines changed as of this January. It is a pleasure to see you here. We look forward to your testimony.

Please proceed.

[The biographical sketch of Mrs. Jones follows:]

## BIOGRAPHICAL INFORMATION

Jeanne M. Jones

Present Postions:

Vice President for Nursing Services
Cumberland Medical Center
Crossville, Tennessee

and

Assistant Professor
Tennessee Technological University

Past Postions:

As supervisor, clinical specialist, primary nurse and staff nurse on medical surgical units.

Educational Experience:

Bachelor of Science in Nursing, Hunter College, New York

Master of Arts, Teachers College, Columbia University, New York

Mast of Education, Teachers College, Columbia University, New York

Membership:

American Nurses' Association
National League of Nursing

Credentials:

Certified Nurse Administrator: Cabinet of Nurse Administrators, American Nurses' Association

Ms. **Jones**. Good morning, Mr. Chairman.

I am here today to present the views and concerns of the American Nurses Association about the influence of rotating shift work on the physical, psychological, and social well-being of professional nurses and their families.

As revealed in the statement that has been submitted for the record, the Association remains concerned about the possible adverse effects of rotating shift work on the productivity and judgments of professional nurses.

In regard to the practice of nursing, researchers have suggested that medication errors, equipment failures, and errors in problem solving are most apt to happen at the low point of the nurse's circadian cycle. For the nurses who are rotating shifts, this low point will occur during their working hours. It is clear that the nurses would be least prepared to process information and make accommodations to the environment when their physical and psychological functions are at resting level.

With regard to rotating shift work, nurses experience the greatest distress when the following conditions of employment exist: Rotation to another shift more frequently than once a week; rotation to as many as three shifts in 1 week; prolonged assignment on undesirable shifts; infrequent weekends off; and inadequate times off between evening and night tours of duty before returning to the day shift.

Studies have revealed that nurses drop out of the labor force or seek employment outside of the hospital in response to these conditions. Required rotating shift work contributes to the continued shortage of nurses in the hospital setting.

In response to the dilemma of providing 24-hour nursing services while minimizing the number of nurses who must rotate to different shifts, a variety of changes in staffing patterns and benefit structures have been initiated. Such changes include increased pay differential for night work, thus increasing the probability that some nurses will work the night shift permanently. Rotation to evening or night shifts on a predictable schedule, such as every 4 or 6 weeks for 1 or 2 weeks, earn a week's pay for 2 12-hour days or nights on a weekend, 7 10-hour days off and 7 10-hour days on, or 12 to 48 hours off between shift rotations.

In some hospitals, these changes have been negotiated through collective bargaining agreements. Many of these alternative staffing patterns are too new to begin to suggest their impact on the welfare of nurses, on the delivery of safe, effective nursing care, or on the ability of a hospital to attract and retain qualified professional nurses.

In summary, the American Nurses Association remains concerned about the potential adverse impact or rotating shift work on the ability of nurses to provide necessary care and services to patients. Continued research efforts are essential to determine the relationship between the desynchronization of circadian rhythms and the quality of care provided to patients in our hospitals.

Thank you for the opportunity to present our views and concerns.

[The prepared statement of Ms. Jones follows:]

## TESTIMONY OF JEANNE JONES, AMERICAN NURSES' ASSOCIATION

The American Nurses' Association is the national professional organization of registered nurses. Its primary purposes are to work for the improvement of health standards and the availability of health care services, to foster high standards of nursing, and to stimulate and promote the professional development of nurses and to advance their economic and general welfare. As the nursing profession's official voice, ANA is responsible for addressing the issues confronting the profession and for working toward goals and objectives that affect all aspects of nursing.

Whereas the numbers of occupational and professional health and non-health related groups that provide twenty-four hour services appear to be increasing, particularly in larger urban areas, the services of professional nurses have been available in hospitals and in some other health care facilities on a twenty-four hour, seven day a week basis for decades. Therefore, individual professionals who provide direct care to patients as well as those who are responsible for administration of the services, particularly in hospitals, have been aware of and concerned about the actual and potential impact of rotating shifts on the physical, psychological, and social well-being of the individual healthcare providers and their families. With respect to the nursing profession, the American Nurses' Association remains concerned with the possible effects of rotating shift work in the productivity and judgements of professional nurses as well as with the possible effects on their general well-being.

Although scientific interest in the area of the effects of rotating shift work on the circadian rhythms of the individual was greatest between the mid-sixties and the mid-seventies, efforts to ameliorate the negative impact of rotating shift work on professional nurses have preceded and followed that time. Because nurses have always been concerned that rotating shift work could result in diminished capacity for the nurse to perform mental and psychomotor tasks and, thus, could jeopardize the health and safety of patients, the efforts of the profession in monitoring the consequences of rotating shift work has been steady and will continue.

## CIRCADIAN RHYTHMS

When environmental conditions are altered by shifting work hours, there are changes in the hours of rising, meal times, social and recreational activities and sleeping and there are accommodations to the environment. Individuals vary in their ability to adjust their time-oriented body functions to different environmental routines. When the hours professional nurses work shifts abruptly, their physiological time is out of synchrony with their enviornmentally determined time. The body rhythms need time to make adjustments, adjustments that require varying amounts of time from subject to subject for any given function and from function to function for a given subject.

In a study conducted by Felton in the mid-seventies, changes in the physiological indicators, such as temperature cycle and sodium excretion levels, demonstrated that the biological clocks of the nurses who rotated shifts got out of phase with the environment in much the same way as those of airline personnel traveling across several time zones in a day. Felton concluded that the subjects averaged one and a quarter hours less sleep during the day when the subjects worked at night, and experienced a poorer quality of sleep, and experienced prolonged fatigue while awake.

Although the psychological and sociological effects of desynchronization of the physiological circadian rhythms were not specifically detailed in the study, changes in coping patterns, in interpersonal relationships, and in the "sense of well-being" have occurred in some subjects. Other researchers have demonstrated that desynchronization in circadian rhythms could lead to psychomotor inefficiency and would exaggerate any feelings of malaise and irritability that might already exist as a result of sleep loss. Additional research has concluded that accidents and errors in tending machines and in problem solving are most likely to happen at the low point in the worker's circadian cycle.

Felton suggested the probability that, in nursing, medication errors, equipment failures, and errors in problem solving are most apt to happen at the low point of the nurses' circadian cycle. It is clear that the nurse would be least prepared to process information and make accommodations to the environment when the physiological and psychological functions are at a resting level.

This testimony should not suggest that any or all professional nurses who work during the evening or night hours in any hospital or health care facility are unsafe or that they present a hazzard to the patients' welfare. Many nurses who work during the night hours do so by choice and do so consistently and do not experience these fluxuations and, therefore, are able and do provide quality patient care. Although the number of budgeted but unfilled positions for evening and night work in a hospital are likely to be greater than that for day work, the majority of individuals who provide care during the evening and night times are full time employees.

Many nurses choose to work during the evening or night shift as they are more accommodating to their personal and family life styles. When the spouse works other than the day time; when children are young and "day" care is unavailable or too expensive; when other obligations, such as attending graduate school, exist; or when the pay differential for evening and night work is significant; nurses may opt to work a shift that best meets their personal needs. Although professional nurses may or may not devote their entire career to employment during these hours, the average nurse on permanent evenings or nights is likely to remain employed in that setting for as long as the average retention rate for all nurses in that facility.

Probably unlike the characteristics of the work activities and work environment for industrial and non-health related professionals, the activities and environment of professional nursing practice varies from shift to shift within the day. For it is people, the patient and the patient's family, who are the recipients of the nursing care. Recuperation and recovery from disease processes and trauma require that the patient have sufficient balance between sleep and wakefulness, between activity and rest. Therefore, modifications in the activities and environment in the hospital from hour to hour are essential to facilitate the recovery process. Because the nature of the professional climate and activities vary, individual work-related preferences can be accommodated.

Therefore, it is the nurse who must periodically rotate to the evening or night shift and the nurse who is a part-time employee who works the evening or night shift who are most likely to experience desynchronization of their circadian cycles. Generally, these nurses would most likely prefer to work during the day time only, are most likely to be relatively recent graduates and are more likely to be younger and unmarried or married without children. In a hospital that has some permanent evening and night professional nurses on staff, the nurses who rotate to other shifts would do so as substitutes for regularly scheduled days off and vacations of the former. In such a circumstance, rotation to another shift could become somewhat predictable. In contrast, for hospitals without permanent full-time employees on every shift, the rotation of professional nurses to other shifts would likely be more frequent, for less predictable periods of time, and involve more nurses at any given time. Hospitals with a greater percentage of permanent evening and night employees are more likely to have more patient beds, more employees, and be located in a more densely populated area.

Unlike the characteristics of usual interaction patterns between professionals and clients, professional nurses who are employed in a facility must be available to provide judgments, assessments, and interventions at any time of the day or night. The amount and variety of nursing care services required and provided to patients during the nighttime varies according to the severity, stability, and complexity of the patients' conditions. Patients who are more acutely ill or who have experienced trauma are more likely to require intensive services abound the clock for one or more days. During the nighttime, in some hospitals, the professional nurse may be the only health care professional that comes in frequent contact with such patients. Because of these characteristics of the practice of professional nursing and because of the early socialization process into the profession while the student nurse is still in school, nurses are aware of the need for nurses to work all shifts and, therefore, they expect to spend some portion of their professional career in other than daytime schedules. In fact, many nurses regard their rotation of shift work in hospitals in the early part of their careers as their means of "paying their dues" to the profession.

The actual extent of shift rotation within the profession is not known by the association; research efforts to document this have been sparse. The association and the professions have focused attention on the conditions of employment that influence the practice of professional nursing. In a study conducted by Wandelt and others in 1980, conditions of work in some hospitals that caused distress for nurses included rotation of shift more frequently than once a week, prolonged assignment on undesireable shifts, and infrequent weekends off; these nurses, "although confident in their abilities," were "ashamed of their practice, worried about their patients, fearful of errors that may be made, and are discouraged." Although these observations by nurses refer to their overall conditions of employment, the influence of the required work on other-than-day shifts on the perceived personal and professional well-being of the nurses is clear. In that same study, the item, unavailability of desired work schedule was ranked high by currently non-employed nurses as a reason for remaining out of the workforce or for leaving or seeking other employment.

Of practical importance and of particular concern to the public, nurses, and the nursing profession would be the incidence and prevalence of inefficient, ineffective, illogical, and erroneous activities by nurses who are experiencing desynchronization due to rotating shift work. Although anecdotal information provided by an individual may suggest a connection between a particular unusual incident with a patient with the status of a nurse's circadian cycle, generalizations or inferences of cause and effect would seem inappropriate. Clearly, the public could benefit from findings of well designed, longitudinal studies on this topic. With limited resources, research priorities for the nation have not focused in this area, however.

Prior to World War II, the usual time schedule of a professional nurse included

12 hour shifts for the equivalent of six days per week. With increased industrialization of the market place, in general, and of hospitals, specifically, the forty hour week and the eight hour day became a reality, and, thus, where twenty-four hour coverage was required, three eight hour shifts per day emerged. Providing sufficient nursing staff to meet the nursing needs of patients for all shifts in a hospital has presented a dilemma for nursing administrators. In response to diminishing morale, and dissatisfaction with conditions of employment, inlcuding required rotation of shift work, and in response to increasing turnover rates for nursing personnel, nursing administrators, by necessity, were required to create new, innovative, and attractive benefit structures and staffing patterns that would increase the possibility of attracting and retaining qualified professional nurses.

In part, the difficulties in retaining professional nurses in hospital work has been due to the increased numbers of positions available outside the hospital for which preparation as a professional nurse is a job requirement. The attractiveness of a 9 a.m. to 5 p.m., Monday through Friday position, such as one in a community based facility or in industry, in contrast with the usual conditions of employment in some hospitals has been partially responsible for the exodus from hospital positions during the past decade.

In order to attract and retain professional nurses, administrators of hospitals have initiated a variety of changes that diminish or regularize the need for rotation of shift work by the majority of nurses in most hospitals. These changes include: increased pay differential for night work; a two, twelve-hour day (7 A.M. to 7 P.M.) or night (7 P.M. to 7 A.M.) on a weekend for a full week's base pay; seven ten hour days of work followed by seven days off; and rotation to evenings or nights for two weeks every six or eight weeks. Many of these alternative staffing patterns are too new to begin to suggest their actual and potential impact on the general welfare of nurses and on the delivery of safe and effective care to patients and families. The concern of the Association is that no data will be collected and analyzed to determine this relationship.

CONCLUSION

The American Nurses' Association remains concerned about the potential impact of rotating shift work on the ability of nurses to provide necessary care and services to patients. The general welfare of nurses remain a major purpose of the Association; the relevance and significance of directing our attention to improving the conditions of employment in the practice environment for the professional nurse remains.

The research efforts that are necessary to determine the relationship between the desynchronization of circadian rhythms and the quality of care provided to patients in hospitals is of concern to the Association; however, Congressional priority and support for a longitudinal study of this relationship would be necessary to ensure adequate resources for such an undertaking. The Association will continue to provide assistance to nursing administrators to devise staffing patterns and other arrangements that will minimize the potential negative effects of rotating shift work.

Mr. GORE. Thank you very much.

We will now hear from Capt. Richard Stone, representing the Airline Pilots Association based here in Washington, D.C.

Captain Stone, welcome.

Captain STONE. Thank you, Mr. Chairman and members of the subcommittee.

I am Richard Stone, human performance project coordinator for the Airline Pilots Association. With me today are Gary Babcock, another airline pilot who serves on our human performance project; John O'Brien, our director of engineering and air safety department; and Bill Edmonds, our staff human factors specialist.

The Airline Pilots Association appreciates this opportunity to participate in these hearings on biological rhythms and shift work scheduling. For those of you who are not familiar with our organization, we represent over 34,000 professional airline pilots who fly for 44 different airlines. This is about 85 percent of the airlines pilots who fly for our domestic and international carriers. We are proud of the fine safety record of these carriers, and feel our organization and the dedication of its members has played an important role in this record.

The Airline Pilots Association has for many years attempted to deal with the problems of diurnal shifting by collective bargaining agreements. We have only been slightly successful. Of course, only a limited number of flights operate during those times which are normal sleep hours. But for those crews who operate these trips, it is no small problem.

In our written presentation, we describe both good and bad trips. One of the bad trips that I would like to briefly describe is one that departs at 6 a.m., which requires the crew to report at 5 a.m., makes five stops and arrives in a layover city just after noon. The downtown hotel is a rest facility for the crew until a departure just before midnight. Five more stops are made before arriving in the next layover city at 10:30 in the morning. The crew then lays over for 20 hours, reporting back to the airport at 6:30 the following morning for a four-stop trip back to their home domicile.

In this trip, the pilot must shift to an early bedtime and early arise before the trip, to the second day when an even earlier bedtime and a late evening arise must occur. The third day that the pilot arrives at the hotel with the problem of trying to stay awake during the day in order to return on early bedtime, early arise.

Every pilot cycles through these good and bad trips thoughout his career, depending on his seniority. What is unusual about our problem with shift work is the fact that our shift work changes are abrupt, erratic, and very irregular.

Yes, we have all the common complaints of the other shift workers, but the inability of the worker to remain in the same pattern, plan his rest or control the environment that he rests in is troublesome. We are not sure what effect this has, but are concerned about its impact.

We have attempted to ascertain the extent of our problems within our association, and we did so in what we called a "fatigue survey." Twelve thousand of our members, which is just over 50 percent, responded to the questionnaire, which was a very complicated questionnaire with some 400 parts. The results demonstate that our members have problems working during hours of normal sleep and multiple time zone crossings. These problems are compounded by typically noisy hotels and the inability to find 24-hour food facilities.

In an attempt to resolve these problems along with our commitment to air safety, we stimulate and cooperate in many research projects. We are currently working closely with NASA-Ames in California in a circadian dysrhythmia study. Operating crews are being physiologically monitored. They complete subjective estimate reports, and keep daily logs in these studies. Study periods cover time off before and after trips, and the trips themselves. Hopefully, this data will provide basic information in rhythms and baseline date for simulator studies in 1985.

Disruption of the diurnal cycle has played an important role in a number of air carrier accidents. Again, our submission goes into greater detail in this area. Like so many other factors in these tragedies, it is difficult to say which factor played the most critical role. We call these factors accident enablers. Circadian dysrhythmia, long work periods, poor nutrition, and high-paced operation are just a few of these enablers. We have had considerable trouble convincing our National Transportation Safety Board, the investigative body charged with this responsibility, to pay attention to these details.

Another matter which concerns our membership is the incidence of coronary heart disease among the members. If we compared data from the Framingham heart study with data of our organization, we find that our members start out with a lower incidence of coronary heart disease—that is 19 per 1,000 for the Framingham population, and 0.2 of 1 percent per 1,000 for the Airline Pilots Association. This is generally acknowledged to be caused by the strict pre-employment criteria of the carriers.

However, toward the end of their careers, there are members who are identical in incidence to the Framingham population with respect to coronary heart disease. Thus, the Framingham population frequency increases sevenfold over the age span between 29 to 59, while the Airline Pilots Association population increases eightyfold over the same period.

We are quick to admit that we do not know the causes of these observed differences. Like the accident data, we see certain commonalities. Rapid cycling of periods of high stress/low stress, rhythm disruptions and common personality types are just a few of the distinct characteristics which typify our membership.

Our association wishes to encourage studies and preparation of guideline material which will aid in the amelioration of the effects of shift work and stress. Studies should deal with both short and long-term effects. These studies should be carried out in the real world. We have seen too many instances of laboratory research, while interesting, that could not be applied to the universe for which they were intended.

It is also important in research to carefully select investigative tools and procedures which apply to normal subjects. We must avoid using techniques of criteria which are used to detect differences in the abnormal and then expect to reach reasonable conclusions about the normal population.

Finally, our association hopes that any changes in legislation or rulemaking which affect the present system of our work rules for airline pilots would be held in abeyance until the results of the NASA study of circadian dysrhythmia are known.

That concludes our testimony, Mr. Chairman. We would be happy to answer any questions. We thank you for this opportunity to appear before the subcommittee.

Mr. GORE. We thank you.

Without objection, the prepared statements of all the witnesses will be included in full in the record. I should have said that at the beginning of the hearing.

I would note particularly that, in your prepared statement, you cite several airline crashes which were preceded by circadian desynchronization or disruption in the normal sleep-wake pattern of the pilots during the period before the crash occurred. These are the kinds of crashes where the phrase "pilot error" sometimes is cited by the NSTB. But certainly your recommendations here will be of tremendous interest, and we will come back for questions.

[The prepared statement of Captain Stone follows:]

STATEMENT OF

RICHARD B. STONE

HUMAN PERFORMANCE PROJECT COORDINATOR

AIR LINE PILOTS ASSOCIATION

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

MARCH 23, 1983

BIOLOGICAL RHYTHMS AND SHIFT WORK SCHEDULING

Mr. Chairman and members of the Subcommittee, I am Richard B. Stone, Human Performance Project Coordinator of the Air Line Pilots Association which represents the professional interests of over 34,000 pilots who fly for 44 airlines. With me today are Gary L. Babcock, member of ALPA's Human Performance Project, and John O'Brien, Director of ALPA's Engineering and Air Safety Department. We appreciate this opportunity to appear before you today to present the views of ALPA in regard to the topic of biological rhythms and shift work scheduling.

## BACKGROUND

In May of 1931, a small group of pilots met in Chicago to form the Air Line Pilots Association. Since that time, a great deal of energy has been expended within our organization in order to provide, as our motto says, "schedule with safety".

Early on it was recognized that in order to provide safe, scheduled air transportation the pilot fatigue issue would have to be addressed. In 1932 the Commerce Department's limit of 110 hours flying time per month was recognized as too high. Then President Behncke of ALPA wrote to Frederick C. Warnishuis, Chairman of the Aeromedical Association for a "scientific" determination of the maximum number of hours which would be compatible with safety. Warnishuis recommended 90-100 hours for day flying, 60-70 for night flying, with a standard figure of 80 hours per month for a combination of both types.

The Air Line Pilots Association has endeavored to apply the recommendation of the Aeromedical Association to scheduling practices since it was received in 1932. The primary vehicle for addressing the fatigue issue to date has been through contract negotiations.

The present method utilized by pilots and their employers, at some carriers, to address the fatigue issue involves limiting the scheduled duty time depending on what time of the day or night the duty period starts. However some carriers and pilot groups operate with duty time limitations.

Attachment #1 illustrates that a report time of 0800 would allow a maximum of 13 hours maximum duty time. If you report at 0200 only 8 hours 30 minutes is allowed to be scheduled. On another carrier, (see Attachment #2) an 0800 check in would allow 13-1/2 hours duty time. An 0200 report time would allow 9-1/2 hours to be scheduled.

In spite of efforts such as these, there are still numerous monthly schedules that must be flown which are well known fatigue-inducing trips.

## WORK SCHEDULES

Today's air carrier pilot schedules are the result of over 50 years of contract negotiations. Every airline has a range of schedules that vary from ideal trips to those that are less than desireable.

As an example of an ideal schedule (see Attachment #3), one major trunk carrier has a B767 three-day trip, or sequence, that flies every Tuesday through Thursday. The first day you depart Chicago's O'Hare at 2:30 p.m. CST, fly 3 legs and arrive Denver at 11:05 p.m. MST. The next day you depart Denver at 2:00 p.m. MST, fly 2 legs and arrive Denver at 9:00 p.m. MST. The third day you depart Denver at 10:10 a.m. MST, fly 3 legs and arrive O'Hare at 10:13 p.m. CST. Most pilots enjoy flying this kind of trip because it involves consistent evening shifts which are easily adaptable to off-duty sleep cycles. The number of legs flown are not excessive and little time is involved sitting around the airport between legs each day.

On the other end of the scale is a four-day sequence flown by B727 crews of the same carrier (see Attachment #4). One schedule for this sequence involves flying Friday through Monday (4 times per month). On the first day you depart O'Hare at 6:45 a.m. CST (5:45 a.m. check-in), fly 4 legs and arrive Portland at 3:25 p.m. PST. The second day's flying involves a departure from Portland at 10:25 a.m. PST with two legs arriving Oklahoma City at 8:50 p.m. CST. The third day you fly one leg between Oklahoma City and Denver departing at 8:30 a.m. CST and arriving at 9:05 a.m. MST. That night you depart Denver at 9:15 p.m. MST and fly two legs to O'Hare arriving at 5:50 a.m. CST the following morning.

This is a difficult sequence to fly for a number of reasons: Your duty days vary constantly from early day shift to evening shift to day shift to night shift. As a result, by the time you arrive at Denver the third day most pilots have difficulty sleeping during the day in order to prepare for the night of flying ahead.

An example of another fatigue-inducing schedule flown by another major air carrier is the following:

Day 1 — Crew reports at 5:00 a.m. PST and flies from Los Angeles to Ontario, Burbank, San Jose, Portland, and Seattle. They are released from duty at 12:30 p.m. PST.

Day 2 — Crew reports at 11:30 p.m. PST and flies from Seattle to Denver, Wichita, Tulsa, Houston and New Orleans. They are released from duty at 10:30 a.m. CST.

Day 3 — Crew reports at 6:20 a.m. CST and flies from New Orleans to Houston, San Antonio, El Paso, and Los Angeles. They are released from duty at 1:00 p.m. PST.

The above sequence of flying is fatigue-inducing due to the following factors:

1. Rapid shift of duty cycles from day to night to day over the three-day sequence.

2. Number of legs flown during each duty period (5, 5, and 4),

3. Time zone effect. After flying all night the second night, the crew must report at 4:20 a.m. home domicile body time. This requires a 3:20 a.m. wake-up call.

Regional and Part 135 air carrier pilots also fly fatigue-inducing schedules. Long duty periods and numerous takeoffs and landings are the rule in most cases. For example, one western regional air carrier's pilot schedules were recently reviewed for fatigue potential. It was found that 43 of 347 or 12% of their rotations have 8 or more landings per duty period.

One mid-west Part 135 air carrier pilot group flies 30 out of a total of 81 sequences (37%) with between 8 and 13 legs per duty day. See Attachment #5 for details. Many of those multi-leg days involve duty periods in excess of 12 hours. Although there are some breaks in the day for rest, very few crew rest facilities are available in the operations areas of Part 135 air carriers.

In another Part 135 operation (see Attachment #6) 7 out of 30 segments, or 23% of the total, require 8 or more landings. One Rocky Mountain region Part 135 pilot group flies 21 out of 65 sequences (32%) with 8 or more landings (see Attachment #7).

While the above examples are only a sampling of the schedules flown by U.S. airline pilots today they do represent the type of fatigue-inducing work rest cycles that must be flown on a daily basis. We have a long way to go in the scheduling area to reduce the potential for future pilot error accidents in which fatigue is one of the enabling elements.

## PROBLEMS

Airline pilots, like other shiftworkers, suffer a whole range of problems as described in many of the scientific papers dealing with this matter. Peculiar to airline pilots is the irregularity with which their work life is shifted. A pilot may maintain a normal day/night cycle for his two-days off and then attempt to prepare for a night-long flight the third, fourth, and fifth days. Once forced into a diurnal reversal, pilots prefer to maintain that cycle through their work cycle of three to four days in length. Unfortunately, some employers are not able to keep crews in the same cycle as demonstrated by our examples of troublesome trip pairings. Another common complaint comes from those pilots on standby (reserve). They standby for five to six days at a time. They very rarely are warned enough in advance to pattern a new rest cycle. It is not unusual to be on a normal day/night rest cycle while on call and then, just prior to retiring, to receive a call to report for flight duty, which may last the rest of the night.

## RESEARCH INVOLVEMENT

The Air Line Pilots Association has had a continuing concern in the area of work/rest cycles. In 1975, results of an Association-wide questionnaire were published in the Air Line Pilot (Attachment #8). The questionnaire was comprehensive (some 400 questions) and was responded to by about 50% of the members (between 12,000 and 13,000) covering all positions of flight status. The work situation is typified by an average of 6 landings per work day. Work times were 64% between 8:00 a.m. and 7:00 p.m., 23% between 7:00 p.m. and 1:00 a.m., and 13% between 1:00 a.m. and 8:00 a.m. Long duty days are usual in the airline pilot work situation. 66% of the responding pilots indicated their work days were between 8 and 13 hours long. In regard to a general question about fatigue, 93% responded that fatigue was a problem. The most common contributor to fatigue was flying hours after midnight. Next most common was long duty days, then multiple landings, and finally time zone changes.

For many years the Air Line Pilots Association has worked closely with NASA-Ames in research projects specifically addressing human factors concerns. More recently we have been involved in a circadian disrythmia study. Both physiological and subjective data is being collected on routine airline trips. This should provide a baseline of data for simulator studies in 1985 aimed at describing performance decrements caused by fatigue-inducing situations. In addition, this work effort at Ames should shortly provide a handbook of recommended measures to ameliorate fatigue-induced situations.

## ACCIDENTS

The Air Line Pilots Association has attempted to encourage all parties within the aviation safety community to improve our understanding of pilot error. When any accident investigation terminates with probable cause -- pilot error, little if any meaningful information is obtained in order to further the cause of accident prevention.

One of the key findings to come out of years of accident investigation by our Association is that pilot error accidents have occurred only after a series of factors termed "accident enablers" have taken place. Accident enablers can multiply and, if not checked, result in sufficient crew performance decrement so that an accident occurs. Commonly found accident enablers include terms such as visual illusions, breakdown in crew interaction, procedural inadequacy, faulty judgement, failures in information transfer and fatigue.

Any attempts to quantify and document fatigue and its effects on the crew by accident investigators have been minimal to date. Very rarely does the National Transportation Safety Board (NTSB) mention the possibility of fatigue having been a factor in accident causation.

In 1967 a DC8 training flight crashed on the approach to New Orleans Airport. Attachment #9 cites the finding by the NTSB that, "...the captain-trainee's performance was affected by some degree of fatigue."

In 1979 a DeHavilland DHC-6-300 crashed during the approach to Hyannis, Massachusetts. Attachment #10 lists in the findings by the NTSB that, "...the crew had worked to a 14-hour duty day involving 9 hours, 15 minutes of flight time." In addition, the Board recommended that the Federal Aviation Administration "expedite rulemaking which would make the flight time and duty time limitations, and rest requirements for commuter air carriers the same as those specified for domestic air carrier crewmembers."

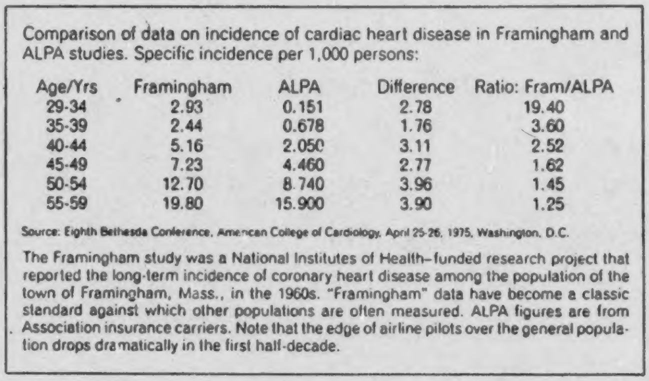
Later in the same year, a DC8 freighter flight crashed into the side of a mountain while holding after an approach to Salt Lake City. Attachment #11 is an analysis of the accident by the Harvard Medical School. The analysis pays particular attention to circadian rest-activity schedule factors that might have played a role in this accident. The report recommended that more data be collected by the NTSB as to actual sleep cycles during the previous 10 days.

On October 31, 1979, a DC10 crashed in Mexico City during an early morning landing. The Mexican government report does not examine the fatigue issue. However, the Air Line Pilots Association accident report will soon be published detailing our concern that fatigue may have played a roll in this tragedy. The three crewmembers had been on normal night/sleep cycle for at least 5 days prior to the accident flight. They reported for duty in Los Angeles at 12:40 p.m. PST and the accident occurred at 3:41 a.m. PST.

We believe the above four accidents illustrate the need for improved accident investigation techniques that address fatigue as one of the key accident enablers which lead up to pilot error. Only when the tools being developed by the research community are applied to the investigation process can we begin to gain a better understanding of the subtle effects of fatigue on crew performance.

## HEALTH CONCERNS

A particular phenomenon exists within the population of airline pilots that concerns the leadership of the Air Line Pilots Association. The following table describes this effect dramatically.



Comparison of data on incidence of cardiac heart disease in Framingham and ALPA studies. Specific incidence per 1,000 persons:

| Age/Yrs | Framingham | ALPA | Difference | Ratio: Fram/ALPA |
|---|---|---|---|---|
| 29-34 | 2.93 | 0.151 | 2.78 | 19.40 |
| 35-39 | 2.44 | 0.678 | 1.76 | 3.60 |
| 40-44 | 5.16 | 2.050 | 3.11 | 2.52 |
| 45-49 | 7.23 | 4.460 | 2.77 | 1.62 |
| 50-54 | 12.70 | 8.740 | 3.96 | 1.45 |
| 55-59 | 19.80 | 15.900 | 3.90 | 1.25 |

Source: Eighth Bethesda Conference, American College of Cardiology, April 25-26, 1975, Washington, D.C.

The Framingham study was a National Institutes of Health–funded research project that reported the long-term incidence of coronary heart disease among the population of the town of Framingham, Mass., in the 1960s. "Framingham" data have become a classic standard against which other populations are often measured. ALPA figures are from Association insurance carriers. Note that the edge of airline pilots over the general population drops dramatically in the first half-decade.

As indicated in the footnote of this table, Framingham data is compared with a 1970 study of ALPA insurance statistics. As can be inferred from this table, the incidence of heart disease among the cohort of age 29-34 was 19 times more frequent in Framingham than ALPA. 19 cases of heart disease were found in the Framingham group while only 1 was found in the ALPA group. Strict selection criteria are usually offered as the explanation for this difference. In each five-year period after age 34 the difference decreases until there appears to be an insignificant difference between the Framingham population and the ALPA population. Thus Framingham changes from an incidence of 3 per 1000 to 20 per 1000, a 7-fold increase. ALPA changes from .2 per 1000 to 16 per 1000, an 80-fold increase. ALPA clearly recognizes that this empirical data is subject to much conjecture. What role or portion of a role played by variations of diurnal periodicity experienced by a career as an airline pilot is indeed questionable. Subjectively we know airline pilots are health conscious and subjected to a system of at least annual physicals and in the case of Captains, semi-annual physicals. We suspect this is one more piece of a complicated mosaic of a work/rest lifestyle that is beset by disruptive change, intense work effort and stress related to performance demands.

## RECOMMENDATIONS

The Air Line Pilots Association feels a pragmatic approach to the question of the debilitating effects of shiftwork must be continued. Pilots have an unusual historical perspective on perceived but as yet unsubstantiated aspects of their work system. Windshear is one such example of this phenomenon. It was not until after years of pleading that an accident investigation proved the existence of this strange enemy. Likewise pilots lament the abrupt shifting of diurnal cycles and multiple time zone crossings which give rise to all manner of complaints. However, they are bombarded by managements economically ill from the effects of deregulation who are trying to convince pilot groups to reverse practices of rest and duty for the sake of productivity.

Nevertheless, this should not deter the research community from continuing its efforts to understand shiftwork consequences. The laboratory gives a perspective of scientific knowledge but in no way can replace studies of real people, in real time, in real life. Thus, we feel the emphasis should be on the worker at work and at home.

We encourage studies like the NASA-Ames research where airline pilots are studied in real work situations. Simulator studies are important here and go beyond the usual laboratory trials. Pilots train and receive checks in simulators and it becomes a part of their work effort. A special need of this type of study is to attempt to understand the performance decrements caused by forces such as time of day, length of work period, etc. Subjects must be airline pilots who are currently qualified and can depict similar subjects in the real world. Volunteer subjects such as college students do not accurately portray the nuances of aircraft operations.

A parallel work effort should continue to attempt to convey to workers realistic strategies that could be employed to enhance their work and leisure life in the face of shiftwork. There seems to be a genuine effort in this direction.

A new emphasis should be placed on the need for research to detect long-range effects of shiftwork. While this may be a project which spans many years, it must be viewed as a time-critical situation for present day workers.

Finally, the Air Line Pilots Association recommends that until we understand the wide ranging effects of shiftwork, legislative change should be approached with the greatest care in those areas that effect worker health, safety and quality of life.

Attachment #1

## SECTION 12 - HOURS OF SERVICE (Continued)

### D. Company Time Card

1. At each pilot base, actual time, scheduled time and pay time shall be posted as expeditiously as possible by the Company for each pilot at the base, such time posted to be that time submitted by the Captain for payroll purposes.

### E. Maximum Duty Hours

1. On domestic operations the maximum time a pilot may be scheduled on duty shall be based on his report time and in accordance with the following schedule:

| Report Time | *Maximum Duty Time |
|---|---|
| 0700-1259 | 13 hours |
| 1300-2059 | 13 hours reduced 1 minute for each 2 minutes between 1300 and report time. |
| 2100-2359 | 9 hours |
| 0000-0059 | 9 hours reduced 30 seconds for each minute between 0000 and report time. |
| 0100-0259 | 8 hours 30 minutes |
| 0300-0359 | 8 hours 30 minutes increased 30 seconds for each minute between 0300 and report time. |
| 0400-0459 | 9 hours increased 3 minutes for each minute between 0400 and report time. |
| 0500-0659 | 12 hours increased 30 seconds for each minute between 0500 and report time. |

*Fractions of less than one minute after these computations shall be considered to be the next higher minute.

Attachment #2

consecutive hours may be scheduled:

(a).

*(duty time limits for schedule preparation)*

| For Duty Period Starting | Trip Preparation |
|---|---|
| 0600-1200 | 13-1/2 hours |
| *1200-2400 | 13-1/2 hours @ 1200, reduced 1 min. for each 3 min. beyond 1200 |
| *0000-0400 | 9-1/2 hours |
| *0400-0600 | 9-1/2 hours @ 0400, increased 2 min. for each 1 min. beyond 0400 |

*When, on a block-to-block basis, the duty period contains a break of at least five (5) hours or twice the number of hours of duty aloft in the duty period preceding the break, whichever is greater, thirteen and one-half (13-1/2) hours shall apply.

(b) When a duty period is scheduled to begin or end with a deadhead segment, the applicable duty limits shall be one (1) hour greater than the times indicated above.

(c) A pilot shall not be scheduled to be on duty for more than ten (10) hours in any duty period following a layover scheduled in accordance with Paragraph G-1-c-(1) of this Section. Between 2301 and 0359, the on-duty period shall not be scheduled to exceed nine (9) hours.

*(duty period limit after field layover)*

(d) Determination of all on-duty periods shall be based on home domicile time.

Attachment #3

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                                               ( SKJ-SUBJECT-CHG-4/24/83)          PAGE  1
DSL EFF 04/01/83 THRU 04/30/83     767    CHICAGO
R/T-FRQ EQP      FLT# DPT ARV DPTR ARVL  L/O   ML  FTM    ACM    DTM      D/C SEG-FRQ
EFF 04/01/83 THRU 04/30/83 XC 04/31                                                 ID 0001
        67M       140 ORD BOS 1430 1735  1.10      2.05   2.05
        67M       377 BOS ORD 1845 2020  1.25 D    2.35   4.40
        67M       237 ORD DEN 2145 2305 14.55      2.20   7.00 10.50    .00
                                          CHERRY CREEK INN
        67M       167 DEN SFO 1400 1527  2.18      2.27   2.27
        67M       236 SFO DEN 1745 2100 13.10      2.15   4.42  8.15    .00
                                          CHERRY CREEK INN
        67M       276 DEN ORD 1010 1322  3.38      2.12   2.12
        67M       908 ORD LGA 1700 2000  1.00      2.00   4.12
        67M       911 LGA ORD 2100 2213            2.13   6.25 12.18    .00
                      T/D-3 BID-18.07* FTM-18.07* TMA-56.58 M$-  8.54 T/C-  -00  6.67*
-------------------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83 XC 04/01 XC 04/02 XC 04/03 XC 04/04                      ID 0002
        67M       918 ORD LGA 0630 0915  1.15      1.45   1.45
        67M       903 LGA ORD 1030 1146  2.39      2.16   4.01
        67M       276 ORD DTW 1425 1621 16.39       .56   4.57 10.06    .08
                                          ~~ANN ARBOR INN, ANN ARBOR~~  HILTON
        67M       955 DTW ORD 0900 0903  3.57      1.03   1.03
        67M       903 ORD MSP 1300 1411   .54      1.11   2.14
        67M       908 MSP ORD 1505 1610            1.05   3.19  9.25   1.23
                      T/D-2 BID-10.00* FTM- 8.16* TMA-34.55 M$-  5.23 T/C-  .13  3.30*
-------------------------------------------------------------------------------------------
EFF 04/15/83 THRU 04/30/83                                                          ID 0003
        67M       902 ORD LGA 0830 1118  2.12  -   1.48   1.48
        67M       905 LGA ORD 1330 1448            2.18   4.06  7.33    .00
                      T/D-1 BID- 5.00* FTM- 4.06* TMA- 7.33 M$-  1.13 T/C-  .54  1.02*
-------------------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83                                                          ID 0004
        67M       910 ORD LGA 2000 2300 20.30      2.00   2.00  3.15    .00
                                          ROOSEVELT
        67M       909 LGA ORD 1930 2100            2.30   2.30  3.45    .00
                      T/D-2 BID-10.00* FTM- 4.30* TMA-26.15 M$-  3.93 T/C- 5.30  3.81*
-------------------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83 XC 04/02                                                 ID 0005
        67M       900 ORD LGA 0715 1000  1.00      1.45   1.45
        67M       167 LGA DEN 1100 1310  3.30 L    4.10   5.55
        27K DH    340 DEN DFW 1640 1926 12.34      1.46   5.55 13.26   1.46
                                          ~~AMERICANA FORT WORTH~~ AMFAC
        67M       493 DFW DEN 0800 0852  1.13      1.52   1.52
        67M       393 DEN SAN 1005 1119  2.11      2.14   4.06
        67M       786 SAN ORD 1330 1910            3.40   7.46 12.25    .00
                      T/D-2 BID-15.27* FTM-13.41* TMA-37.10 M$-  5.57 T/C-  .00  5.69*
-------------------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83 XC 04/03                                                 ID 0006
        67M       157 ORD SEA 1840 2055 10.50 D    4.15   4.15  5.30    .00
                                          JET INN, SEATTLE
        67M       140 SEA ORD 0745 1330            3.45   3.45  5.00    .00
                      T/D-2 BID-10.00* FTM- 8.00* TMA-20.05 M$-  3.01 T/C- 2.00  3.68*
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                                                                       PAGE 2
DSL EFF 04/01/83 THRU 04/30/83    767    CHICAGO
R/T-FRQ EQP    FLT# DPT ARV DPTR ARVL  L/D  ML  FTM   ACM   DTM   D/C SEG-FRQ
EFF 04/15/83 THRU 04/30/83                                                 ID 0007
        67M     205 ORD DEN 1550 1720  1.15     2.30  2.30
        67M     916 DEN ORD 1835 2139           2.04  4.34  7.04   .00
                   T/D-1 BID- 5.00* FTM- 4.34* TMA- 7.04 M$- 1.06 T/C-  .26  1.02*
----------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83 XC 04/01 XC 04/02                               ID 0008
        67M     907 ORD PDX 1850 2105 10.55 D   4.15  4.15  5.30   .00
                                      FLAMINGO MOTEL, PORTLAND
        67M     906 PDX ORD 0800 1335   .55 L   3.35  3.35
        67M     122 ORD CLE 1430 1633   .57     1.03  4.38
        67M     721 CLE ORD 1730 1744           1.14  5.52  8.59   .00
                   T/D-2 BID-10.07* FTM-10.07* TMA-24.09 M$- 3.62 T/C-  .00  3.60*
----------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83 XC 04/01 XC 04/02                               ID 0009
        67M     955 ORD PHX 1010 1240  2.15     3.30  3.30
        67M     910 PHX ORD 1455 1900  1.05     3.05  6.35
        67M     786 ORD DTW 2005 2200 19.40      .55  7.30 12.05   .00
                                      ANN ARBOR INN, ANN ARBOR
        67M     157 DTW ORD 1740 1742  1.03     1.02  1.02
        67M     721 ORD OMA 1845 2005 13.15     1.20  2.22  4.40   .00
                                      MARRIOTT
        67M     904 OMA ORD 0920 1034   .56     1.14  1.14
        67M     904 ORD LGA 1130 1414  2.16     1.44  2.58
        67M     907 LGA ORD 1630 1753           2.23  5.21  9.48   .00
                   T/D-3 BID-16.16* FTM-15.13* TMA-56.58 M$- 8.54 T/C- 1.03  5.78*
----------------------------------------------------------------------------------
EFF 04/02/83 THRU 04/02/83                                                 ID 0010
OSA     67M     122 ORD CLE 1430 1633   .57     1.03  1.03
OSA     67M     721 CLE ORD 1730 1744  2.16     1.14  2.17
OSA     67M DH  910 ORD LGA 2000 2300 11.30     2.00  2.17  8.45  2.06
                                      ROOSEVELT
OSU     67M     903 LGA ORD 1030 1146  5.14     2.16  2.16
                                      CARAVELLE MOTOR INN
OSU     27E DH  322 ORD DTW 1700 1859 14.01      .59  2.16  9.44  2.36
                                      ANN ARBOR INN, ANN ARBOR
OMO     67M     955 DTW ORD 0900 0903  3.57     1.03  1.03
OMO     67M     903 ORD MSP 1300 1411   .54     1.11  2.14
OMO     67M     908 MSP ORD 1505 1610           1.05  3.19  9.25  1.23
                   T/D-3 BID-15.00* FTM- 7.52* TMA-50.55 M$- 7.63 T/C- 1.03   .19*
----------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/01/83                                                 ID 0011
OFR     67M     140 ORD BOS 1430 1735  1.10     2.05  2.05
OFR     67M     377 BOS ORD 1845 2020  1.25 D   2.35  4.40
OFR     67M     237 ORD DEN 2145 2305 17.35     2.20  7.00 10.50   .00
                                      CHERRY CREEK INN
OSA     27K DH  340 DEN DFW 1640 1926 12.34     1.46   .00  3.01  1.46
                                      AMERICANA FORT WORTH
OSU     67M     493 DFW DEN 0800 0852  1.13     1.52  1.52
OSU     67M     393 DEN SAN 1005 1119  2.11     2.14  4.06
OSU     67M     786 SAN ORD 1330 1910           3.40  7.46 12.25   .00
                   T/D-3 BID-16.32* FTM-14.46* TMA-53.55 M$- 8.08 T/C-  .00   .21*
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LINE CONSTRUCTION SUMMARY FOR APRIL 1983 ORD 767 PRIM **BIDS CLOSE 0600 FRI MAR 11** SKED SBJT TO CHG 4/24          VERSION 1  1
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LINE 301  CR.   77.15    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 200.56   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   76.37               005                         005         005             005                         005
DAYS OFF  C/I    0.00    *   *   * DFWORD *   *   *   *   * DFWORD * DFWORD *   * DFWORD *   *   *   *   * DFWORD *   .
   20     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 302  CR.   77.15    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 185.50   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   68.25   005             005                         005                         005                         005
DAYS OFF  C/I    0.00   DFWORD *   * DFWORD *   *   *   *   * DFWORD *   *   *   *   * DFWORD *   *   *   *   * DFWORD *   *   *
   20     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 303  CR.   77.15    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 185.50   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   68.25           005                                     005                         005             005     005
DAYS OFF  C/I    0.00    *   * DFWORD *   *   *   *   *   *   *   * DFWORD *   *   *   *   * DFWORD *   * DFWORD * DFWORD *   *
   20     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 304  CR.   76.27    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 190.50   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   63.56       017             005         005                         005                         005                         005
DAYS OFF  C/I    0.00    * DTWORD *   * DFWORD * DFWORD *   *   *   *   * DFWORD *   *   *   *   * DFWORD *   *   *   *   * DFWORD
   19     C/O    7.46
------------------------------------------------------------------------------------------------------------------------------
LINE 305  CR.   78.20    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 202.35   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   69.30   011                         005                         005                         005                         005
DAYS OFF  C/I    0.00   DENDFWORD *   *   *   * DFWORD *   *   *   *   * DFWORD *   *   *   *   * DFWORD *   *   *   *   * DFWORD
   19     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 306  CR.   79.15    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 190.50   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   70.25                           005         008                         005             005                         005     004
DAYS OFF  C/I    0.00    *   *   *   *   *   * DFWORD * DFWORD *   *   *   *   * DFWORD *   * DFWORD *   *   *   *   * DFWORDLGAORD
   19     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 307  CR.   77.28    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 235.25   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   76.34               001                         001                         001                         003001
DAYS OFF  C/I    0.00    *   *   * DENDENORD *   *   *   * DENDENORD *   *   *   * DENDENORD *   *   * ORDDENDENORD *   *   *
   17     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 308  CR.   77.28    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 234.56   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   77.02                   001                         001                         001                         007001
DAYS OFF  C/I    0.00    *   *   *   * DENDENORD *   *   *   * DENDENORD *   *   *   * DENDENORD *   *   * ORDDENDENORD *   *
   17     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 309  CR.   77.28    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 234.56   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   77.02                       001                         001                     007001                          001
DAYS OFF  C/I    0.00    *   *   *   *   * DENDENORD *   *   *   * DENDENORD *   *   * ORDDENDENORD *   *   *   * DENDENORD *
   17     C/O    0.00
------------------------------------------------------------------------------------------------------------------------------
LINE 310  CR.   77.28    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5
          TAFB 234.56   FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH  FR(SA SU)MO TU  WE  TH
          BLK   77.02                           001                         001                         001         007             001
DAYS OFF  C/I    0.00    *   *   *   *   *   * DENDENORD *   *   *   * DENDENORD *   *   *   * DENDENORDORD *   *   * DENDENORD
   17     C/O    0.00
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LINE CONSTRUCTION SUMMARY FOR APRIL 1983 ORD 767 PRIM **BIDS CLOSE 0600 FRI MAR 11** SKED SBJT TO CHG 4/24        VERSION 1 ②
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LINE 311  CR.    76.03    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  220.30   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    74.15                        001                  001                003001               003001
DAYS OFF  C/I     0.00    •  •  •  •  •  •  • DENDENORD •  •  •  • DENDENORD •  •  • ORDDENDENORD •  •  • ORDDENDENORD
   17     C/O     6.25
---------------------------------------------------------------------------------------------------------------------------
LINE 312  CR.    79.23    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  238.22   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    79.23      001                  001                  001                  001                  001
DAYS OFF  C/I     0.00    • DENDENORD •  •  •  • DENDENORD •  •  •  • DENDENORD •  •  •  • DENDENORD •  •  •  • DENDENORD
   17     C/O    11.12
---------------------------------------------------------------------------------------------------------------------------
LINE 313  CR.    77.28    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  235.25   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    76.34         001                  001               003001                  001
DAYS OFF  C/I     0.00    •  • DENDENORD •  •  •  • DENDENORD •  •  • ORDDENDENORD •  •  •  • DENDENORD •  •  •  •
   17     C/O     0.00
---------------------------------------------------------------------------------------------------------------------------
LINE 314  CR.    72.34    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  242.42   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    68.22            009                  009                  009                  009            009
DAYS OFF  C/I     0.00    •  •  • DTWOMAORD •  •  •  • DTWOMAORD •  •  •  • DTWOMAORD •  •  •  • DTWOMAORD •  • DTWOMAORD
   17     C/O     8.46
---------------------------------------------------------------------------------------------------------------------------
LINE 315  CR.    75.64    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  235.26   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    64.50               009                  009            003009                     009      003
DAYS OFF  C/I     0.00    •  •  •  • DTWOMAORD •  •  •  • DTWOMAORD •  •  • ORDDTWOMAORD •  •  •  • DTWOMAORD ORD
   16     C/O     0.00
---------------------------------------------------------------------------------------------------------------------------
LINE 316  CR.    79.26    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  258.21   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    75.14                  009      008         009                  009                  009      006
DAYS OFF  C/I     0.00    •  •  •  •  • DTWOMAORDPDXORD •  • DTWOMAORD •  •  •  • DTWOMAORD •  •  •  • DTWOMAORDSEAORD
   15     C/O     5.45
---------------------------------------------------------------------------------------------------------------------------
LINE 317  CR.    80.18    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  274.15   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    73.48   018                  009                  009                     009      003         009
DAYS OFF  C/I     0.00   DTWOMAORD •  •  • DTWOMAORD •  •  •  • DTWOMAORD •  •  •  •  • DTWOMAORDORD •  •  • DTWOMAORD
   15     C/O     6.24
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LINE 318  CR.    74.41    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  241.06   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    68.39      016                  009                  009      007            009                  008
DAYS OFF  C/I     0.00  - • DTWOMAORD •  •  • DTWOMAORD •  •  •  • DTWOMAORDORD •  •  •  • DTWOMAORD •  •  •  • PDXORD
   16     C/O     5.52
---------------------------------------------------------------------------------------------------------------------------
LINE 319  CR.    75.11    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  252.01   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    70.57         009                  009                  008            009                  009
DAYS OFF  C/I     0.00    •  • DTWOMAORD •  •  • DTWOMAORD •  •  •  • PDXORD •  •  • DTWOMAORD •  •  •  • DTWOMAORD
   16     C/O     0.00
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LINE 320  CR.    73.48    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB  248.04   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK    58.01      010      004               009               009                     009
DAYS OFF  C/I     0.00    • LGADTWORDLGAORD •  •  • DTWOMAORD •  •  • DTWOMAORD •  •  •  •  • DTWOMAORD •  •  •  •
   14     C/O     0.00
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Attachment #4

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                                                                    PAGE 9
DSL EFF 04/01/83 THRU 04/30/83    727     CHICAGO
R/T-FRQ EQP    FLT# DPT ARV DPTR ARVL  L/O  ML  FTM    ACM   DTM     D/C SEG-FRQ
EFF 04/15/83 THRU 04/30/83                                                ID 0139
      27K      770 ORD ROC 0645 0907   .29       1.22  1.22
      27K      770 ROC BUF 0936 1000  1.30        .24  1.46
      27K      321 BUF ORD 1130 1159  1.11       1.29  3.15
      27E      153 ORD PDX 1310 1525 19.00 L     4.15  7.30 11.55    .00
                                     BENSON HOTEL, PORTLAND
      27E      152 PDX ORD 1025 1605  2.45       3.40  3.40
      27K      893 ORD OKC 1850 2050 11.40       2.00  5.40  9.40    .00
                                     HILTON AIRPORT
      27K      785 OKC DEN 0830 0905 12.10       1.35  1.35  2.50    .00
                                     CHERRY CREEK INN
      27E      673 DEN PDX 2115 2245  1.35       2.30  2.30
      27E      156 PDX ORD 0020 0550             3.30  6.00  8.50    .00
                   T/D-4 BID-20.45* FTM-20.45* TMA-72.20 MS-108.50 T/C-  .00  4.22
---------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/11/83                                                ID 0140
      27K      816 ORD SRQ 1145 1510  4.10       2.25  2.25
                                     RAMADA INN
      27K      821 SRQ ORD 1920 2100             2.40  5.05 10.30    .10
                   T/D-1 BID- 5.15* FTM- 5.05* TMA-10.30 MS- 15.75 T/C-  .00   .73
---------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83                                                ID 0141
      27K      832 ORD SYR 0700 0931  1.29       1.31  1.31
      27K      871 SYR ORD 1100 1150  2.25       1.50  3.21
      27E      242 ORD BDL 1415 1709   .26       1.54  5.15
      27E      242 BDL PVD 1735 1802 13.38        .27  5.42 11.17    .00
                                     HOLIDAY INN DOWNTOWN
      27K      709 PVD ORD 0740 0905  2.40       2.25  2.25
      27K      350 ORD ALB 1145 1433  2.22       1.48  4.13
      27K      789 ALB ORD 1655 1759             2.04  6.17 12.34    .01
                   T/D-2 BID-12.00* FTM-11.59* TMA-36.14 MS- 54.35 T/C-  .00  4.57
---------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/30/83 XC 04/01 XC 04/03                              ID 0142
XTH   27K      838 ORD SDF 1705 1908 12.22       1.03  1.03  2.18    .06
                                     HOLIDAY INN SOUTH
XFR   27K      621 SDF ORD 0730 0733   .57       1.03  1.03
XFR   27E      102 ORD YYZ 0830 1046   .51       1.16  2.19
XFR   27E      485 YYZ ORD 1137 1204   .56       1.27  3.46
XFR   27E      531 ORD PHX 1300 1535 20.25 L     3.35  7.21 11.20    .00
                                     RAMADA VALLEY HO
XSA   27E      452 PHX ORD 1200 1605  1.00       3.05  3.05
XSA   27X      848 ORD JFK 1705 2012  1.33 D     2.07  5.12              XSA
XSA   27X      387 JFK ORD 2145 2310             2.25  7.37 11.25    .00 XSA
                   T/D-3 BID-16.07* FTM-16.01* TMA-55.20 MS- 83.00 T/C-  .00  4.91
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                                                                                 PAGE 10
DSL EFF 04/01/83 THRU 04/30/83      727     CHICAGO
R/T-FRQ EQP     FLT# DPT ARV DPTR ARVL  L/O  ML  FTM   ACM   DTM    D/C SEG-FRQ
EFF 04/01/83 THRU 04/30/83                                                   ID 0143
OTH       27K      838 ORD SDF 1705 1908 12.22     1.03  1.03  2.18   .06
                                        HOLIDAY INN SOUTH
OFR       27K      621 SDF ORD 0730 0733   .57     1.03  1.03
OFR       27E      102 ORD YYZ 0830 1046   .51     1.16  2.19
OFR       27E      485 YYZ ORD 1137 1204   .56     1.27  3.46
OFR       27E      531 ORD PHX 1300 1535 20.25 L   3.35  7.21 11.20   .00
                                        RAMADA VALLEY HO
OSA       27E      452 PHX ORD 1200 1605           3.05  3.05  4.20   .00
                        T/D-3 BID-15.00* FTM-11.29* THA-48.15 MS- 72.37 T/C- 3.25   .76
--------------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/14/83                                                   ID 0144
          27E      878 ORD TPA 0835 1159  1.31     2.24  2.24
          27E      873 TPA ORD 1330 1505           2.35  4.59  7.45   .00
                        T/D-1 BID- 5.00* FTM- 4.59* THA- 7.45 MS- 11.63 T/C-  .01   .89
--------------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/14/83 XC 04/01 XC 04/02                                 ID 0145
          27E      902 ORD LGA 0830 1118  2.12     1.48  1.48
          27E      905 LGA ORD 1330 1448  2.57     2.18  4.06
          27K      710 ORD RDU 1745 2029 11.31     1.44  5.50 12.14   .17
                                        TRIANGLE HOTEL, RALEIGH
          27K      219 RDU ORD 0800 0859  4.06     1.59  1.59
                                        CARAVELLE MOTOR INN
          27E      703 ORD DSM 1305 1415 16.30     1.10  3.09  8.30  1.06
                                        MARRIOTT
          27B      808 DSM ORD 0645 0744   .51      .59   .59
          27B      808 ORD FLL 0835 1220   .40     2.45  3.44
          27B      443 FLL ORD 1300 1459       L   2.59  6.43  9.29   .00
                        T/D-3 BID-17.05* FTM-15.42* THA-55.44 MS- 83.60 T/C-  .00  2.60
--------------------------------------------------------------------------------------
EFF 04/01/83 THRU 04/14/83                                                   ID 0146
          27E      905 ORD SLC 1550 1805   .30     3.15  3.15
          27E      905 SLC EUG 1835 1920 14.05     1.45  5.00  6.45   .00
                                        VALLEY RIVER INN, EUGENE
          27E      200 EUG SLC 0925 1153   .37     1.28  1.28
          27E      200 SLC ORD 1230 1614  2.26     2.44  4.12
          27K      741 ORD SAT 1840 2130 19.55     2.50  7.02 11.20   .00
                                        MARRIOTT INN DOWNTOWN
          27K      306 SAT IAH 1725 1815   .30      .50   .50
          27K      306 IAH ORD 1845 2103           2.18  3.08  4.53   .00
                        T/D-3 BID-15.33* FTM-15.10* THA-54.28 MS- 81.70 T/C-  .23  2.76
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LINE CONSTRUCTION SUMMARY FOR APR 83 ORD 727 PRIM LOF(BIDS CLOSE 0600 MAR.11,83)(SCHED SBJT TO CHG 4/24/83)      VERSION 11

LINE 601  CR.   77.28    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 263.44   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   77.28                  133                  138                  139                  139
DAYS OFF  C/I    0.00    *  *  *  *  * ORRSMFORD *  *  *  * PDXOKCDENORD *  *  * PDXOKCDENORD *  *  * PDXOKCDENORD
   15     C/O    0.00

LINE 602  CR.   78.45    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 283.15   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   78.45                  138                     138                  139                  139
DAYS OFF  C/I    0.00    *  *  *  *  * PDXOKCDENORD *  *  *  * PDXOKCDENORD *  *  * PDXOKCDENORD *  *  * PDXOKCDENORD
   15     C/O    4.15

LINE 603  CR.   80.35    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 267.10   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   80.35                        138         116      139                  139                  139
DAYS OFF  C/I    0.00    *  *  *  *  *  *  * PDXOKCDENORDORD *  * PDXOKCDENORD *  *  * PDXOKCDENORD *  *  * PDXOKCDENORD
   15     C/O    7.35

LINE 604  CR.   77.28    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 263.44   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   77.28      138                  138                        133               139
DAYS OFF  C/I    0.00    * PDXOKCDENORD *  *  * PDXOKCDENORD *  *  *  *  * ORRSMFORD *  *  * PDXOKCDENORD *  *  *
   15     C/O    0.00

LINE 605  CR.   77.28    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 263.44   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   77.28         138                  138                  139                  133
DAYS OFF  C/I    0.00    *  * PDXOKCDENORD *  *  * PDXOKCDENORD *  *  * PDXOKCDENORD *  *  * ORRSMFORD *  *  *  *
   15     C/O    0.00

LINE 606  CR.   77.28    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 263.44   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   77.28   138                              138                  133               139
DAYS OFF  C/I    0.00   PDXOKCDENORD *  *  *  *  *  *  * PDXOKCDENORD *  *  * ORRSMFORD *  *  * PDXOKCDENORD *  *
   15     C/O    0.00

LINE 607  CR.   77.28    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 263.44   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   77.28   133               138                        139                  139
DAYS OFF  C/I    0.00   ORRSMFORD *  *  * PDXOKCDENORD *  *  *  *  * PDXOKCDENORD *  *  * PDXOKCDENORD *  *  *  *
   15     C/O    0.00

LINE 608  CR.   76.05    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 233.40   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   76.05      133               133               133               133               133
DAYS OFF  C/I    0.00    * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *
   15     C/O    0.00

LINE 609  CR.   76.05    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 233.40   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   76.05         133               133               133               133               133
DAYS OFF  C/I    0.00    *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *
   15     C/O    0.00

LINE 610  CR.   76.05    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 233.40   FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK   76.05            133               133               133               133               133
DAYS OFF  C/I    0.00    *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD
   15     C/O    0.00
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LINE CONSTRUCTION SUMMARY FOR APR 83 ORD 727 PRIM LOF(BIDS CLOSE 0600 MAR.11.83)(SCHED SBJT TO CHG 4/24/83)      VERSION 6
LINE 611  CR.     77.26    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 234.30    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     77.00              133         104      133               133                  133                  133
DAYS OFF  C/I      0.00    *  *  *  * ORRSMFORINDORD *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD *  *  * ORRSMFORD
   15     C/O      3.37
LINE 612  CR.     78.20    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 228.15    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     68.05           129               140140129                      132   132      130               132      130
DAYS OFF  C/I      0.00    *  *  * IND - ORD *  * ORDORDIND - ORD *  *  *  * IND - IND - ORDORD *  *  * IND - ORDORD
   12     C/O      0.00
LINE 613  CR.     74.20    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 216.20    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     64.25              129            130124   129         130                  132               132   132
DAYS OFF  C/I      0.00    *  *  *  * IND - ORD * ORD - ORDIND - ORD * ORD *  *  *  * IND - ORD *  * IND - IND - ORD
   12     C/O      0.00
LINE 614  CR.     76.45    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 242.35    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     68.30    129   124                 129                  129   124               132   132               132
DAYS OFF  C/I      0.00    IND -  - ORD *  *  * IND - ORD *  *  *  * IND -  - ORD *  *  * IND - IND - ORD *  * IND - ORD
   12     C/O      6.45
LINE 615  CR.     80.37    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 241.25    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     76.27        129   129            129   129         129                     124                  133
DAYS OFF  C/I      0.00    *  * IND - ORDIND - ORD * IND - ORDIND - ORD * IND - ORD *  *  *  *  - ORD *  *  *  * ORRSMFORD
   12     C/O      8.36
LINE 616  CR.     78.25    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 217.31    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     70.10        152            133      144      133      136                  136                  117
DAYS OFF  C/I      0.00    *  * ORD *  *  * ORRSMFORDORD *  * ORRSMFORD * RDUDSMORD *  *  *  * RDUDSMORD *  *  * PVDORD
   15     C/O      2.49
LINE 617  CR.     78.10    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 164.13    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     68.22    156         108   104140104104104   104104         134132               132            139
DAYS OFF  C/I      0.00    ORD *  *  * ORD * ORDORDORDORDORD * ORDORD *  *  * ORDIND - ORD *  *  * IND - ORD *  * PDXOKCDENORD
   13     C/O     13.15
LINE 618  CR.     79.48    1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5
          TAFB 239.22    FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH FR(SA SU)MO TU WE TH
          BLK     75.13    119      108      129      145         129                     128
DAYS OFF  C/I      0.00    SANORD * ORD *  * IND - ORDRDUDSMORD * IND - ORD *  *  *  *  *  *  * LASPHXORD *  *  *  *
   15     C/O      0.00
```

SECONDARY LINES Capt Bid 619—636 F/O BID 619-628 S/O BID 619-630

Attachment #5

## Air Wisconsin

Summary

| Flt | Landings | Flt | Ldgs |
|---|---|---|---|
| 408 | 8 | 469 | 8 |
| 418 | 8 | 472 | 9 |
| 409 | 9 | 462 | 11 |
| 410 | 13 | 155 | 10 |
| 411 | 8 | 153 | 10 |
| 415 | 13 | 151 | 11 |
| 412 | 10 | 154 | 10 |
| 414 | 8 | 157 | 9 |
| 416 | 8 | 156 | 10 |
| 417 | 9 | 159 | 8 |
| 419 | 8 | | |
| 453 | 9 | | |
| 458 | 12 | | |
| 459 | 10 | | |
| 460 | 8 | | |
| 463 | 10 | | |
| 464 | 11 | | |
| 466 | 8 | | |
| 467 | 9 | | |
| 468 | 8 | | |

:. FLT. CONTROL

RAY - HERE ARE YOUR trip SHEETS FOR Air Wisconsin trips.

Tony

ATW DHC-7

AIR WISCONSIN TRIP SCHEDULE EFF. 02-15-83 thru 04-23-83

Trip 407 Freq. M-TH

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 170 | ATW | ORD* | 0645 | 0740 | :50 | :55 | | |
| 262 | ORD | MKG | 0830 | 1012 | :13 | :42 | | |
| | MKG | BTL | 1025 | 1050 | :35 | :25 | | |
| 265 | BTL | MKG | 1125 | 1150 | :10 | :25 | | |
| | MKG | ORD* | 1200 | 1145 | :55 | :45 | | |
| 175 | ORD | ATW | 1240 | 1329 | :-- | :49 | | |
| | | | Totals | | | 4:01 | 0744 | 0744 |

Trip 408^418 Freq. M-T-W

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 172 | ATW | OSH | 0800 | 0813 | :07 | :13 | | |
| | OSH | ORD* | 0820 | 0910 | 1:50 | :50 | | |
| 322 | ORD | EKI | 1100 | 1232 | :13 | :32 | | |
| | EKI | BTL | 1245 | 1307 | :38 | :22 | | |
| 323 | BTL | EKI | 1345 | 1407 | :13 | :22 | | |
| | EKI | ORD* | 1420 | 1404 | 1:26 | :44 | | |
| 177 | ORD | ATW | 1530 | 1619 | :31 | :49 | | |
| 178 | ATW | ORD | 1650 | 1745 | 17:55 | :55 | | |
| | | | Totals | | | 4:47 | 1045 | 1645 |

⑧

Ramada Inn (312)827-5131

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 700 | ORD | TOL | 1140 | 1340 | :15 | :60 | | |
| | TOL | DTW | 1355 | 1415 | :30 | :20 | | |
| 665 | DTW | FWA* | 1445 | 1529 | 2:11 | :44 | | |
| 664 | FWA | DTW | 1740 | 1820 | :30 | :40 | | |
| 609 | DTW | FWA | 1850 | 1934 | :16 | :44 | | |
| | FWA | SBN | 1950 | 2015 | :12 | :25 | | |
| | SBN | ORD | 2027 | 2005 | :35 | :38 | | |
| 189 | ORD | ATW | 2040 | 2129 | :-- | :49 | | |
| | | | Totals | | | 5:20 | 1049 | 2144 |
| | | | | | | 10:07 | 2134 | 3829 |

⑧

Trip 408^422 Freq. Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 172 | ATW | OSH | 0800 | 0813 | :07 | :13 | | |
| | OSH | ORD* | 0820 | 0910 | 1:50 | :50 | | |
| 322 | ORD | EKI | 1100 | 1232 | :13 | :32 | | |
| | EKI | BTL | 1245 | 1307 | :38 | :22 | | |
| 323 | BTL | EKI | 1345 | 1407 | :13 | :22 | | |
| | EKI | ORD* | 1420 | 1404 | 1:26 | :44 | | |
| 177 | ORD | ATW | 1530 | 1619 | :31 | :49 | | |
| 178 | ATW | ORD | 1650 | 1745 | 18:45 | :55 | | |
| | | | Totals | | | 4:47 | 1045 | 1645 |

⑧

Ramada Inn (312)827-5131

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 34 | ORD | SBN | 1230 | 1400 | :15 | :30 | | |
| | SBN | MKG | 1415 | 1445 | :45 | :30 | | |
| 35 | MKG | SBN | 1530 | 1600 | :12 | :30 | | |
| | SBN | ORD | 1612 | 1550 | :30 | :38 | | |
| 460 | ORD | LAF | 1620 | 1758 | :32 | :38 | | |
| 471 | LAF | ORD | 1830 | 1815 | :25 | :45 | | |
| 179 | ORD | ATW | 1840 | 1929 | :— | :49 | | |
| | | | Totals | | | 4:20 | 759 | 1944 |
| | | | | | | 9:07 | 1844 | 3629 |

Trip 409^410 Freq. F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 172 | ATW | OSH | 0800 | 0813 | :07 | :13 | | |
| | OSH | ORD | 0820 | 0910 | :50 | :50 | | |
| 634 | ORD | SBN | 1000 | 1130 | :10 | :30 | | |
| | SBN | FWA | 1140 | 1205 | :15 | :25 | | |
| | FWA | TOL | 1220 | 1250 | :10 | :30 | | |
| | TOL | PIT | 1300 | 1405 | :55 | 1:05 | | |
| 635 | PIT | TOL | 1500 | 1605 | :10 | 1:05 | | |
| | TOL | FWA* | 1615 | 1645 | 1:45 | :30 | | |
| 667 | FWA | ORD | 1830 | 1825 | 13:35 | :55 | | |
| | | | Totals | | | 6:03 | 1125 | 1645 |

⑨

Ramada Inn (312)827-5131

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 590 | ORD | EKI | 0800 | 0932 | :13 | :32 | | |
| | EKI | FWA | 0945 | 1008 | :32 | :23 | | |
| 531 | FWA | EKI | 1040 | 1103 | :12 | :23 | | |
| | EKI | ORD | 1115 | 1059 | :31 | :44 | | |
| 554 | ORD | SBN | 1130 | 1300 | :15 | :30 | | |
| | SBN | FWA | 1315 | 1340 | :15 | :25 | | |
| | FWA | TOL | 1355 | 1425 | :10 | :30 | | |
| | TOL | CLE | 1435 | 1510 | 1:05 | :45 | | |
| 555 | CLE | TOL | 1615 | 1650 | :10 | :35 | | |
| | TOL | FWA | 1700 | 1730 | :15 | :30 | | |
| | FWA | SBN | 1745 | 1810 | :10 | :25 | | |
| | SBN | ORD | 1820 | 1758 | :42 | :38 | | |
| 179 | ORD | ATW | 1840 | 1929 | :-- | :49 | | |
| | | | Totals | | | 7:09 | 1229 | 1944 |
| | | | | | | 13:12 | 2354 | 3629 |

⑬

Trip 411^415 Freq. Sa

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 172 | ATW | OSH | 0800 | 0813 | :07 | :13 | | |
| | OSH | ORD | 0820 | 0910 | 3:20 | :50 | | |
| 34 | ORD | SBN | 1230 | 1400 | :15 | :30 | | |
| | SBN | MKG | 1415 | 1445 | :45 | :30 | | |
| 35 | MKG | SBN | 1530 | 1600 | :12 | :30 | | |
| | SBN | ORD* | 1612 | 1550 | 2:10 | :38 | | |
| 528 | ORD | SBN | 1800 | 1930 | :10 | :30 | | |
| | SBN | TOL | 1940 | 2020 | 13:10 | :40 | | |
| | | | Totals | | | 4:21 | 1220 | 1645 |

⑧

Airport Motel (312)865-5531

# ATW DHC7

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 33 | TOL | SBN | 0930 | 1010 | :12 | :40 | | |
| | SBN | ORD | 1022 | 1000 | 1:00 | :38 | | |
| 322 | ORD | EKI | 1100 | 1232 | :13 | :32 | | |
| | EKI | BTL | 1245 | 1307 | :38 | :22 | | |
| 323 | BTL | EKI | 1345 | 1407 | :13 | :22 | | |
| | EKI | ORD | 1420 | 1404 | 1:11 | :44 | | |
| 664 | ORD | SBN | 1515 | 1645 | :15 | :30 | | |
| | SBN | FWA | 1700 | 1725 | :15 | :25 | | |
| | FWA | DTW | 1740 | 1820 | :30 | :40 | | |
| 609 | DTW | FWA | 1850 | 1934 | :16 | :44 | | |
| | FWA | SBN | 1950 | 2015 | :12 | :25 | | |
| | SBN | ORD | 2027 | 2005 | :35 | :38 | | |
| 189 | ORD | ATW | 2040 | 2129 | :-- | :49 | | |
| | | | Totals | | | 7:29 | 1359 | 2144 |
| | | | | | | 11:53 | 2619 | 3829 |

⑬

Trip 412^418 Freq. Su

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 172 | ATW | OSH | 0800 | 0813 | :07 | :13 | | |
| | OSH | ORD | 0800 | 0910 | :50 | :50 | | |
| 634 | ORD | SBN | 1000 | 1130 | :10 | :30 | | |
| | SBN | FWA | 1140 | 1205 | :15 | :25 | | |
| | FWA | TOL | 1220 | 1250 | :10 | :30 | | |
| | TOL | PIT | 1300 | 1405 | :55 | 1:05 | | |
| 635 | PIT | TOL | 1500 | 1605 | :10 | 1:05 | | |
| | TOL | FWA* | 1615 | 1645 | :40 | :30 | | |
| 655 | FWA | SBN | 1725 | 1750 | :12 | :25 | | |
| | SBN | ORD | 1802 | 1740 | 18:00 | :38 | | |
| | | | Totals | | | 6:11 | 1040 | 1625 |

⑩

Ramada Inn (312)827-5131

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 700 | ORD | TOL | 1140 | 1340 | :15 | 1:00 | | |
| | TOL | DTW | 1355 | 1415 | :30 | :20 | | |
| 665 | DTW | FWA* | 1445 | 1529 | 2:11 | :44 | | |
| 664 | FWA | DTW | 1740 | 1820 | :30 | :44 | | |
| 609 | DTW | FWA | 1850 | 1934 | :16 | :44 | | |
| | FWA | SBN | 1950 | 2015 | :12 | :25 | | |
| | SBN | ORD | 2027 | 2005 | :35 | :38 | | |
| 189 | ORD | ATW | 2040 | 2129 | :-- | :49 | | |
| | | | Totals | | | 5:20 | 1049 | 2144 |
| | | | | | | 11:31 | 2129 | 3829 |

⑧

Trip 414 Freq. Su.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| D/H172 | ATW | ORD* | 0[illegible] | 0910 | 3:20 | :00 | | |
| 34 | ORD | SBN | [illegible] | 1400 | :15 | :30 | | |
| | SBN | MK[illegible] | [illegible]15 | 1445 | :45 | :30 | | |
| 35 | MKG | S[illegible] | 1530 | 1600 | :12 | :30 | | |
| | SBN | ORD | 1612 | 1550 | :30 | :38 | | |
| 460 | ORD | LAF | 1620 | 1758 | :32 | :38 | | |
| 471 | LAF | ORD | 1830 | 1815 | :25 | :45 | | |
| 179 | ORD | ATW | 1840 | 1929 | :-- | :49 | | |
| | | | Totals | | | 4:20 | 1229 | 1229 |

⑧

Trip 416 Freq. M-Th

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 174 | ATW | ORD* | 1005 | 1100 | 1:30 | :55 | | |
| 34 | ORD | SBN | 1230 | 1400 | :15 | :30 | | |
| | SBN | MKG | 1415 | 1445 | :45 | :30 | | |
| 35 | MKG | SBN | 1530 | 1600 | :12 | :30 | | |
| | SBN | ORD | 1612 | 1550 | :30 | :38 | | |
| 460 | ORD | LAF | 1620 | 1758 | :32 | :38 | | |
| 471 | LAF | ORD | 1830 | 1815 | :25 | :45 | | |
| 179 | ORD | ATW | 1840 | 1929 | :-- | :49 | | |
| | | | Totals | | | 5:15 | 1024 | 1024 |

⑧

Trip 417 Freq. F.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 174 | ATW | ORD | 1005 | 1100 | :40 | :55 | | |
| 700 | ORD | TOL | 1140 | 1340 | :15 | 1:00 | | |
| | TOL | DTW | 1355 | 1415 | :40 | :20 | | |
| 665 | DTW | FWA* | 1455 | 1529 | 2:11 | :44 | | |
| 664 | FWA | DTW | 1740 | 1820 | :30 | :40 | | |
| 609 | DTW | FWA | 1850 | 1934 | :16 | :44 | | |
| | FWA | SBN | 1950 | 2015 | :12 | :25 | | |
| | SBN | ORD | 2027 | 2005 | :35 | :38 | | |
| 189 | ORD | ATW | 2040 | 2129 | :-- | :49 | | |
| | | | Totals | | | 6:15 | 1224 | 1224 |

⑨

Trip 419^404 Freq. M-T-W

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 124 | ATW | OSH | 1225 | 1238 | :07 | :13 | | |
| | OSH | ORD | 1245 | 1335 | :25 | :50 | | |
| 694 | ORD | EKI | 1400 | 1532 | :13 | :32 | | |
| | EKI | FWA | 1545 | 1608 | :32 | :23 | | |
| 697 | FWA | EKI | 1640 | 1703 | :12 | :23 | | |
| | EKI | ORD* | 1715 | 1659 | 1:31 | :44 | | |
| 728 | ORD | SBN | 1830 | 2000 | :10 | :30 | | |
| | SBN | TOL | 2010 | 2050 | 10:20 | :40 | | |
| | | | Totals | | | 4:15 | 825 | 1220 |

⑧

Airport Motel (419)865-5531

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 701 | TOL | SBN | 0710 | 0750 | :12 | :40 | | |
| | SBN | ORD* | 0802 | 0740 | :30 | :38 | | |
| 30 | ORD | SBN | 0810 | 0940 | :42 | :30 | | |
| 33 | SBN | ORD | 1022 | 1000 | :30 | :38 | | |
| 123 | ORD | OSH | 1030 | 1114 | :11 | :44 | | |
| | OSH | ATW | 1125 | 1138 | :-- | :13 | | |
| | | | Totals | | | 3:23 | 628 | 1153 |
| | | | | | | 7:38 | 1453 | 2413 |

ATW DHC7

⑧

Trip 419^405 Freq. Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 124 | ATW | OSH | 1225 | 1238 | :07 | :13 | | |
| | OSH | ORD | 1245 | 1335 | :25 | :50 | | |
| 694 | ORD | EKI | 1400 | 1532 | :13 | :32 | | |
| | EKI | FWA | 1545 | 1608 | :32 | :23 | | |
| 697 | FWA | EKI | 1640 | 1703 | :12 | :23 | | |
| | EKI | ORD* | 1715 | 1659 | 1:31 | :44 | | |
| 728 | ORD | SBN | 1830 | 2000 | :10 | :30 | | |
| | SBN | TOL | 2010 | 2050 | 10:20 | :40 | | |
| | | | Totals | | | 4:15 | 825 | 1220 |
| | Airport Hotel (419)865-5531 | | | | | | | |
| 701 | TOL | SBN | 0710 | 0750 | :12 | :40 | | |
| | SBN | ORD | 0802 | 0740 | :50 | :38 | | |
| 262 | ORD | MKG | 0830 | 1012 | :13 | :42 | | |
| | MKG | BTL | 1025 | 1050 | :35 | :25 | | |
| 265 | BTL | MKG | 1125 | 1150 | :10 | :25 | | |
| | MKG | ORD* | 1200 | 1145 | :55 | :45 | | |
| 175 | ORD | ATW | 1240 | 1329 | :— | :49 | | |
| | | | Totals | | | 4:24 | 819 | 1344 |
| | | | | | | 8:39 | 1644 | 2604 |

Trip 420^406 Freq. F.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 124 | ATW | OSH | 1225 | 1238 | :07 | :13 | | |
| | OSH | ORD* | 1245 | 1335 | 1:55 | :50 | | |
| 177 | ORD | ATW | 1530 | 1619 | :31 | :49 | | |
| 178 | ATW | ORD* | 1650 | 1745 | :45 | :55 | | |
| 728 | ORD | SBN | 1830 | 2000 | :10 | :30 | | |
| | SBN | TOL | 2010 | 2050 | 10:20 | :40 | | |
| | | | Totals | | | 3:57 | 825 | 1220 |
| | Airport Hotel (419)865-5531 | | | | | | | |
| 701 | TOL | SBN | 0710 | 0750 | :12 | :40 | | |
| | SBN | ORD | 0802 | 0740 | :50 | :38 | | |
| 262 | ORD | MKG | 0830 | 1012 | :13 | :42 | | |
| | MKG | BTL | 1025 | 1050 | :40 | :25 | | |
| 563 | BTL | SBN | 1130 | 1152 | :10 | :22 | | |
| | SBN | ORD* | 1202 | 1140 | 1:00 | :38 | | |
| D/H175 | ORD | ATW | 1240 | 1329 | :-- | :00 | | |
| | | | Totals | | | 3:25 | 819 | 1344 |
| | | | | | | 7:22 | 1644 | 2604 |

Trip 421^413 Freq. Sa.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 124 | ATW | OSH | 1225 | 1238 | :07 | :13 | | |
| | OSH | ORD | 1245 | 1335 | 3:50 | :50 | | |
| 266 | ORD | MKG | 1725 | 1907 | :13 | :42 | | |
| | MKG | BTL | 1920 | 1945 | 13:15 | :25 | | |
| | | | Totals | | | 2:10 | 720 | 1220 |
| | Stouffer's (616)963-7050 | | | | | | | |
| 561 | BTL | MKG | 0900 | 0925 | :10 | :25 | | |
| | MKG | ORD | 0935 | 0920 | 1:10 | :45 | | |
| 123 | ORD | OSH | 1030 | 1114 | :11 | :44 | | |
| | OSH | ATW | 1125 | 1138 | :47 | :13 | | |
| 124 | ATW | OSH | 1225 | 1238 | :07 | :13 | | |
| | OSH | ORD* | 1245 | 1335 | 1:55 | :50 | | |
| 177 | ORD | ATW | 1530 | 1619 | :-- | :49 | | |
| | | | Totals | | | 3:59 | 919 | 1634 |
| | | | | | | 6:09 | 1639 | 2854 |

Trip 423^401 Freq. S-M-T-W

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 176 | ATW | ORD* | 1400 | 1455 | 2:05 | :55 | | |
| 706 | ORD | TOL | 1700 | 1900 | :30 | 1:00 | | |
| 707 | TOL | ORD | 1930 | 1945 | :30 | 1:15 | | |
| 268 | ORD | MKG | 2015 | 2157 | :13 | :42 | | |
| | MKG | BTL | 2210 | 2235 | 8:25 | :25 | | |
| | | | Totals | | | 4:17 | 835 | 1045 |
| | Stouffer's (616)963-7050 | | | | | | | |
| 261 | BTL | MKG | 0700 | 0725 | :10 | :25 | | |
| | MKG | ORD | 0735 | 0720 | :25 | :45 | | |
| 121 | ORD | OSH | 0745 | 0829 | :11 | :44 | | |
| | OSH | ATW | 0840 | 0853 | :— | :13 | | |
| | | | | | | 2:07 | 353 | 908 |
| | | | | | | 6:24 | 1228 | 1953 |

Trip 423^402 Freq. Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 176 | ATW | ORD* | 1400 | 1455 | 2:05 | :55 | | |
| 706 | ORD | TOL | 1700 | 1900 | :30 | 1:00 | | |
| 707 | TOL | ORD | 1930 | 1945 | :30 | 1:15 | | |
| 268 | ORD | MKG | 2015 | 2157 | :13 | :42 | | |
| | MKG | BTL | 2210 | 2235 | 8:25 | :25 | | |
| | | | Totals | | | 4:17 | 835 | 1045 |
| | Stouffer's (616)963-7050 | | | | | | | |
| 261 | BTL | MKG | 0700 | 0725 | :10 | :25 | | |
| | MKG | ORD | 0735 | 0720 | :50 | :45 | | |
| 30 | ORD | SBN | 0810 | 0940 | :42 | :30 | | |
| 33 | SBN | ORD | 1022 | 1000 | :30 | :38 | | |
| 123 | ORD | OSH | 1030 | 1114 | :11 | :44 | | |
| | OSH | ATW | 1125 | 1138 | :-- | :13 | | |
| | | | Totals | | | 3:15 | 638 | 1153 |
| | | | | | | 7:32 | 1513 | 2238 |

ATW DHC7

Trip 423^403 Freq. F.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 176 | ATW | ORD* | 1400 | 1455 | 2:05 | :55 | | |
| 706 | ORD | TOL | 1700 | 1900 | :30 | 1:00 | | |
| 707 | TOL | ORD | 1930 | 1945 | :30 | 1:15 | | |
| 268 | ORD | MKG | 2015 | 2157 | :13 | :42 | | |
| | MKG | BTL | 2210 | 2235 | 8:25 | :25 | | |
| | | | Totals | | | 4:17 | 835 | 1045 |
| | Stouffer's (616)963-7050 | | | | | | | |
| 261 | BTL | MKG | 0700 | 0725 | :10 | :25 | | |
| | MKG | ORD* | 0735 | 0720 | 3:10 | :45 | | |
| 123 | ORD | OSH | 1030 | 1114 | :11 | :44 | | |
| | OSH | ATW | 1125 | 1138 | :— | :13 | | |
| | | | Totals | | | 2:07 | 638 | 1153 |
| | | | | | | 6:24 | 1513 | 2238 |

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Trip 424^404 Freq. Su:

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 178 | ATW | ORD* | 1650 | 1745 | :45 | :55 | | |
| 728 | ORD | SBN | 1830 | 2000 | :10 | :30 | | |
| | SBN | TOL | 2010 | 2050 | 10:20 | :40 | | |
| | | | Totals | | | 2:05 | 400 | 755 |
| | Airport Motel (419)865-5531 | | | | | | | |
| 701 | TOL | SBN | 0710 | 0750 | :12 | :40 | | |
| | SBN | ORD* | 0802 | 0740 | :30 | :38 | | |
| 30 | ORD | SBN | 0810 | 0940 | :42 | :30 | | |
| 33 | SBN | ORD | 1022 | 1000 | :30 | :38 | | |
| 123 | ORD | OSH | 1030 | 1114 | :11 | :44 | | |
| | OSH | ATW | 1125 | 1138 | :— | :13 | | |
| | | | Totals | | | 3:23 | 628 | 1153 |
| | | | | | | 5:28 | 1028 | 1948 |

ATW SW-4

AIR WISCONSIN TRIP SCHEDULE EFF. 02-15-83 thru 04-23-83

Trip 103 Freq. M-F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 901 | ATW | MSP | 0710 | 0810 | :35 | 1:00 | | |
| 900 | MSP | ATW | 0845 | 0940 | 3:20 | :55 | | |
| 905 | ATW | MSP | 1300 | 1400 | :45 | 1:00 | | |
| 904 | MSP | ATW | 1445 | 1540 | :-- | :55 | | |
| | | | Totals | | | 3:50 | 930 | 930 |

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Trip 105^101 Freq. S-M-T-W-Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 907 | ATW | MSP | 1620 | 1720 | :40 | 1:00 | | |
| 906 | MSP | ATW | 1800 | 1855 | :35 | :55 | | |
| 128 | ATW | ORD | 1930 | 2020 | :30 | :50 | | |
| 480 | ORD | LAF | 2050 | 2228 | 9:37 | :38 | | |
| | | | Totals | | | 3:23 | 608 | 825 |

Holiday Inn (317)567-2131

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 401 | LAF | ORD | 0805 | 0750 | 1:10 | :45 | | |
| 400 | ORD | LAF | 0900 | 1038 | :52 | :38 | | |
| 403 | LAF | ORD | 1130 | 1115 | 1:35 | :45 | | |
| 430 | ORD | LAF | 1250 | 1428 | 1:02 | :38 | | |
| 461 | LAF | ORD | 1530 | 1515 | 1:30 | :45 | | |
| 125 | ORD | ATW | 1645 | 1727 | :-- | :42 | | |
| | | | Totals | | | 4:13 | 1122 | 1742 |
| | | | | | | 7:36 | 1730 | 2607 |

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Trip 105^102 Freq. F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 907 | ATW | MSP | 1620 | 1720 | :40 | 1:00 | | |
| 906 | MSP | ATW | 1800 | 1855 | :35 | :55 | | |
| 128 | ATW | ORD | 1930 | 2020 | :30 | :50 | | |
| 480 | ORD | LAF | 2050 | 2228 | 9:37 | :38 | | |
| | | | Totals | | | 3:23 | 608 | 825 |

Holiday Inn (317)567-2131

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 401 | LAF | ORD | 0805 | 0750 | 1:10 | :45 | | |
| 400 | ORD | LAF | 0900 | 1038 | :52 | :38 | | |
| 40[illegible] | LAF | ORD | 1130 | 1115 | 1:25 | :45 | | |
| 175 | ORD | ATW | 1240 | 1329 | :-- | :49 | | |
| | | | Totals | | | 2:57 | 724 | 1344 |
| | | | | | | 6:20 | 1332 | 2209 |

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Trip 106^104 Freq. Sa.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 176 | ATW | ORD | 1400 | 1455 | 1:25 | :55 | | |
| 460 | ORD | LAF | 1620 | 1758 | :32 | :38 | | |
| 471 | LAF | ORD | 1830 | 1815 | :45 | :45 | | |
| 570 | ORD | LAF | 1900 | 2038 | 14:52 | :38 | | |
| | | | Totals | | | 2:56 | 638 | 1045 |

Holiday Inn (317)567-2131

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 403 | LAF | ORD | 1130 | 1115 | 1:35 | :45 | | |
| 450 | ORD | LAF | 1250 | 1428 | 1:02 | :38 | | |
| 461 | LAF | ORD | 1530 | 1515 | 1:30 | :45 | | |
| 125 | ORD | ATW | 1645 | 1727 | :-- | :42 | | |
| | | | Totals | | | 2:50 | 757 | 1742 |
| | | | | | | 5:46 | 1435 | 2827 |

FWA DHC-7

AIR WISCONSIN TRIP SCHEDULE EFFECTIVE 02-15-83 thru /

Trip 451 Freq. M-F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 691 | FWA | EKI | 0645 | 0708 | :12 | :23 | | |
| | EKI | ORD | 0720 | 0704 | :26 | :44 | | |
| 652 | ORD | SBN | 0730 | 0900 | :15 | :30 | | |
| | SBN | FWA | 0915 | 0940 | :15 | :25 | | |
| | FWA | CLE | 0955 | 1048 | :52 | :53 | | |
| 653 | CLE | FWA | 1140 | 1235 | :-- | :55 | | |
| | | | Totals | | | 3:50 | 650 | 650 |

Trip 452 Freq. M-Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 650 | FWA | TOL | 0710 | 0740 | :10 | :30 | | |
| | TOL | CLE | 0750 | 0825 | :50 | :35 | | |
| 731 | CLE | TOL | 0915 | 0950 | :10 | :35 | | |
| | TOL | FWA | 1000 | 1030 | :10 | :30 | | |
| | FWA | ORD | 1040 | 1035 | :55 | :55 | | |
| 654 | ORD | SBN | 1130 | 1300 | :15 | :30 | | |
| | SBN | FWA | 1315 | 1340 | :-- | :25 | | |
| | | | Totals | | | 4:00 | 730 | 730 |

Trip 453 Freq. F.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 650 | FWA | TOL | 0710 | 0740 | :10 | :30 | | |
| | TOL | CLE | 0750 | 0825 | :50 | :35 | | |
| 731 | CLE | TOL | 0915 | 0950 | :10 | :35 | | |
| | TOL | FWA | 1000 | 1030 | :10 | :30 | | |
| | FWA | ORD | 1040 | 1035 | :55 | :55 | | |
| 654 | ORD | SBN | 1130 | 1300 | :15 | :30 | | |
| | SBN | FWA | 1315 | 1340 | :15 | :25 | | |
| | FWA | CLE | 1355 | 1448 | 1:27 | :53 | | |
| 655 | CLE | FWA | 1615 | 1710 | :-- | :55 | | |
| | | | Totals | | | 5:48 | 1100 | 1100 |

9

Trip 454 Freq. M-Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 630 | FWA | TOL | 0730 | 0800 | :10 | :30 | | |
| | TOL | PIT | 0810 | 0915 | 1:00 | 1:05 | | |
| 631 | PIT | TOL | 1015 | 1120 | :10 | 1:05 | | |
| | TOL | FWA | 1130 | 1200 | :10 | :30 | | |
| | FWA | ORD | 1210 | 1205 | :55 | :55 | | |
| 662 | ORD | FWA | 1300 | 1449 | :-- | :49 | | |
| | | | Totals | | | 4:54 | 819 | 819 |

Trip 455 Freq. M-Th

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 661 | FWA | ORD | 0800 | 0755 | :45 | :55 | | |
| 690 | ORD | EKI | 0840 | 1012 | :13 | :32 | | |
| | EKI | FWA | 1025 | 1048 | :37 | :23 | | |
| 663 | FWA | SBN | 1125 | 1150 | :12 | :25 | | |
| | SBN | ORD* | 1202 | 1140 | 3:35 | :38 | | |
| 664 | ORD | SBN | 1515 | 1645 | :15 | :30 | | |
| | SBN | FWA | 1700 | 1725 | :-- | :25 | | |
| | | | Totals | | | 3:48 | 1025 | 1025 |

Trip 456 Freq. F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 661 | FWA | ORD | 0800 | 0755 | :45 | :55 | | |
| 690 | ORD | EKI | 0840 | 1012 | :13 | :32 | | |
| | EKI | FWA | 1025 | 1048 | :37 | :23 | | |
| 663 | FWA | SBN | 1125 | 1150 | :12 | :25 | | |
| | SBN | ORD* | 1202 | 1140 | 2:20 | :38 | | |
| 694 | ORD | EKI | 1400 | 1532 | :13 | :32 | | |
| | EKI | FWA | 1545 | 1608 | :-- | :23 | | |
| | | | Totals | | | 3:48 | 908 | 908 |

Trip 458 Freq. Sa

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 591 | FWA | EKI | 0800 | 0823 | :12 | :23 | | |
| | EKI | ORD | 0835 | 0819 | :31 | :44 | | |
| 730 | ORD | SBN | 0850 | 1020 | :10 | :30 | | |
| | SBN | TOL | 1030 | 1110 | :20 | :40 | | |
| 631 | TOL | FWA | 1130 | 1200 | :10 | :30 | | |
| | FWA | ORD | 1210 | 1205 | 1:10 | :55 | | |
| 574 | ORD | FWA | 1315 | 1504 | :11 | :49 | | |
| | FWA | TOL | 1515 | 1545 | :30 | :30 | | |
| 575 | TOL | FWA | 1615 | 1645 | :10 | :30 | | |
| | FWA | ORD* | 1655 | 1650 | :20 | :55 | | |
| 596 | ORD | EKI | 1710 | 1842 | :13 | :32 | | |
| | EKI | FWA | 1855 | 1918 | :-- | :23 | | |
| | | | Totals | | | 7:21 | 1218 | 1218 |

12

Trip 459 Freq. M-Th

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 693 | FWA | EKI | 0900 | 0923 | :12 | :23 | | |
| | EKI | ORD* | 0935 | 0919 | :41 | :44 | | |
| 634 | ORD | SBN | 1000 | 1130 | :10 | :30 | | |
| | SBN | FWA* | 1140 | 1205 | 1:55 | :25 | | |
| 733 | FWA | ORD | 1400 | 1355 | :25 | :55 | | |
| 264 | ORD | MKG | 1420 | 1602 | :13 | :42 | | |
| | MKG | BTL | 1615 | 1640 | :30 | :25 | | |
| 267 | BTL | MKG | 1710 | 1735 | :10 | :25 | | |
| | MKG | ORD | 1745 | 1730 | :30 | :45 | | |
| 606 | ORD | FWA | 1800 | 1949 | :-- | :49 | | |
| | | | Totals | | | 6:03 | 1149 | 114 |

10

FWA DHC7

rip 460 Freq. F

| lt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 93 | FWA | EKI | 0900 | 0923 | :12 | :23 | | |
| | EKI | ORD | 0935 | 0919 | 1:41 | :44 | | |
| 22 | ORD | EKI | 1100 | 1232 | :13 | :22 | | |
| | EKI | BTL | 1245 | 1307 | :38 | :22 | | |
| 23 | BTL | EKI | 1345 | 1407 | :13 | :22 | 8 | |
| | EKI | ORD | 1420 | 1404 | 1:11 | :44 | | |
| 64 | ORD | SBN | 1515 | 1645 | :15 | :30 | | |
| | SBN | FWA | 1700 | 1725 | :15 | :25 | | |
| | | | Totals | | | 4:02 | 925 | 925 |

rip 461 Freq. Su

| lt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 593 | FWA | EKI | 0900 | 0923 | :12 | :23 | | |
| | EKI | ORD | 0935 | 0919 | 2:11 | :44 | | |
| 554 | ORD | SBN | 1130 | 1300 | :15 | :30 | | |
| | SBN | FWA | 1315 | 1340 | :15 | :25 | | |
| | FWA | CLE | 1355 | 1448 | 1:27 | :53 | | |
| 555 | CLE | FWA | 1615 | 1710 | :— | :55 | | |
| | | | Totals | | | 3:50 | 910 | 910 |

Trip 463 Freq. Su

| Flt | Dpt | Arv | Dptr- | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 530 | FWA | TOL | 1035 | 1105 | :15 | :30 | | |
| | TOL | CLE | 1120 | 1155 | :35 | :35 | | |
| 733 | CLE | TOL | 1230 | 1305 | :10 | :35 | | |
| | TOL | FWA | 1315 | 1345 | :15 | :30 | | |
| | FWA | ORD | 1400 | 1355 | :25 | :55 | | |
| 264 | ORD | MKG | 1420 | 1602 | :13 | :42 | 10 | |
| | MKG | BTL | 1615 | 1640 | :30 | :25 | | |
| 267 | BTL | MKG | 1710 | 1735 | :10 | :25 | | |
| | MKG | ORD | 1745 | 1730 | :30 | :45 | | |
| 606 | ORD | FWA | 1800 | 1949 | :— | :49 | | |
| | | | Totals | | | 6:11 | 1014 | 1014 |

Trip 464 Freq. Su

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 663 | FWA | SBN | 1125 | 1150 | :12 | :25 | | |
| | SBN | ORD* | 1202 | 1140 | 2:20 | :38 | | |
| 694 | ORD | EKI | 1400 | 1532 | :13 | :32 | | |
| | EKI | FWA | 1545 | 1608 | :32 | :23 | | |
| 697 | FWA | EKI | 1640 | 1703 | :12 | :23 | 11 | |
| | EKI | ORD | 1715 | 1659 | :26 | :44 | | |
| 266 | ORD | MKG | 1725 | 1907 | :13 | :42 | | |
| | MKG | BTL | 1920 | 1945 | :10 | :25 | | |
| | BTL | DTW | 1955 | 2030 | :30 | :35 | | |
| 629 | DTW | TOL | 2100 | 2120 | :10 | :20 | | |
| | TOL | FWA | 2130 | 2200 | :— | :30 | | |
| | | | Totals | | | 5:37 | 1135 | 1135 |

Trip 465 Freq. F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 631 | FWA | ORD | 1210 | 1205 | :55 | :55 | | |
| 662 | ORD | FWA | 1300 | 1449 | :29 | :49 | | |
| | FWA | DTW | 1520 | 1600 | 1:15 | :40 | | |
| 667 | DTW | TOL | 1715 | 1735 | :10 | :30 | | |
| | TOL | FWA | 1745 | 1815 | :— | :30 | | |
| | | | Totals | | | 3:14 | 705 | 705 |

Trip 466 Freq. M-Th

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 634 | FWA | TOL | 1220 | 1250 | :10 | :30 | | |
| | TOL | PIT | 1300 | 1405 | :55 | 1:05 | | |
| 635 | PIT | TOL | 1500 | 1605 | :10 | 1:05 | | |
| | TOL | FWA | 1615 | 1645 | :30 | :30 | | |
| 636 | FWA | TOL | 1715 | 1745 | :10 | :30 | | 8 |
| | TOL | PIT | 1755 | 1900 | 1:00 | 1:05 | | |
| 637 | PIT | TOL | 2000 | 2105 | :10 | 1:05 | | |
| | TOL | FWA | 2115 | 2145 | :— | :30 | | |
| | | | Totals | | | 6:20 | 1025 | 1025 |

Trip 467 Freq. M-Th

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 653 | FWA | SBN | 1250 | 1315 | :12 | :25 | | |
| | SBN | ORD | 1327 | 1305 | :40 | :38 | | |
| 704 | ORD | TOL | 1345 | 1545 | :30 | 1:00 | | |
| 705 | TOL | ORD* | 1615 | 1630 | :55 | 1:15 | | |
| 266 | ORD | MKG | 1725 | 1907 | :13 | :42 | | 9 |
| | MKG | BTL | 1920 | 1945 | :10 | :25 | | |
| | BTL | DTW | 1955 | 2030 | :30 | :35 | | |
| 629 | DTW | TOL | 2100 | 2120 | :10 | :20 | | |
| | TOL | FWA | 2130 | 2200 | :— | :30 | | |
| | | | Totals | | | 5:50 | 1010 | 1010 |

Trip 468 Freq. F&Su

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 653 | FWA | SBN | 1250 | 1315 | :12 | :25 | | |
| | SBN | ORD | 1327 | 1305 | :40 | :38 | | |
| 704 | ORD | TOL | 1345 | 1545 | :30 | 1:00 | | |
| 705 | TOL | ORD* | 1615 | 1630 | 1:45 | 1:15 | | |
| 396 | ORD | EKI | 1815 | 1947 | :33 | :32 | | 8 |
| 399 | EKI | ORD | 2020 | 2004 | :56 | :44 | | |
| 698 | ORD | EKI | 2100 | 2232 | :13 | :32 | | |
| | EKI | FWA | 2245 | 2308 | :— | :23 | | |
| | | | Totals | | | 5:29 | 1118 | 1118 |

# FWA DHC7

Trip 469 Freq. M-Th

| Flt | Dpt | Arv | Arvl | Dptr | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 654 | FWA | CLE | 1355 | 1448 | 1:27 | :53 | | |
| 655 | CLE | FWA | 1615 | 1710 | :15 | :55 | | |
| | FWA | SBN | 1725 | 1750 | :12 | :25 | | |
| | SBN | ORD* | 18o2 | 1740 | :35 | :38 | | |
| 396 | ORD | EKI | 1815 | 1947 | :33 | :32 | | |
| 399 | EKI | ORD | 2020 | 2004 | :56 | :44 | | |
| 698 | ORD | EKI | 2110 | 2232 | :13 | :32 | | |
| | EKI | FWA | 2245 | 2308 | :-- | :23 | | |
| | | | Totals | | | 5:02 | 913 | 913 |

⑧

Trip 470 Freq. F

| Flt | Dpt | Arv | Arvl | Dptr | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 733 | FWA | ORD | 1400 | 1355 | :25 | :55 | | |
| 264 | ORD | MKG | 1420 | 1602 | :13 | :42 | | |
| | MKG | BTL | 1615 | 1640 | :30 | :25 | | |
| 267 | BTL | MKG | 1710 | 1735 | :10 | :25 | | |
| | MKG | ORD | 1745 | 1730 | :30 | :45 | | |
| 606 | ORD | FWA | 1800 | 1949 | :— | :49 | | |
| | | | Totals | | | 4:01 | 649 | 649 |

Trip 471 457 Freq. S-M-T-W-Th

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 662 | FWA | DTW | 1520 | 1600 | 1:15 | :40 | | |
| 667 | DTW | TOL | 1715 | 1735 | :10 | :20 | | |
| | TOL | FWA | 1745 | 1815 | :15 | :30 | | |
| | FWA | ORD | 1830 | 1825 | 1:35 | :55 | | |
| 608 | ORD | FWA | 2000 | 2149 | :11 | :49 | | |
| | FWA | TOL | 2200 | 2230 | 9:30 | :30 | | |
| | | | Totals | | | 3:44 | 810 | 1025 |
| | Airport Motel (419)865-5531 | | | | | | | |
| 703 | TOL | ORD | 0800 | 0815 | :35 | 1:15 | | |
| 730 | ORD | SBN | 0850 | 1020 | :10 | :30 | | |
| | SBN | TOL | 1030 | 1110 | :10 | :40 | | |
| | TOL | CLE | 1120 | 1155 | :35 | :35 | | |
| 733 | CLE | TOL | 1230 | 1305 | :10 | :35 | | |
| | TOL | FWA | 1315 | 1345 | :— | :30 | | |
| | | | Totals | | | 4:05 | 645 | 1300 |
| | | | | | | 7:49 | 1455 | 2325 |

Trip 472 Freq. S-M-T-W-Th-F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 665 | FWA | ORD | 1545 | 1540 | :50 | :55 | | |
| 656 | ORD | SBN | 1630 | 1800 | :15 | :30 | | |
| | SBN | FWA | 1815 | 1840 | :20 | :25 | | |
| | FWA | CLE | 1900 | 1953 | :47 | :53 | | |
| 657 | CLE | FWA | 2040 | 2135 | :15 | :55 | | |
| | FWA | SBN | 2150 | 2215 | :12 | :25 | | |
| | SBN | ORD | 2227 | 2205 | :25 | :38 | | |
| 668 | ORD | SBN | 2230 | 2359 | :11 | :29 | | |
| | SBN | FWA | 2410 | 2435 | :— | :25 | | |
| | | | Totals | | | 5:35 | 950 | 950 |

⑨

Trip 473 Freq. F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 697 | FWA | EKI | 1640 | 1703 | :12 | :23 | | |
| | EKI | ORD | 1715 | 1659 | :26 | :44 | | |
| 266 | ORD | MKG | 1725 | 1907 | :13 | :42 | | |
| | MKG | BTL | 1920 | 1945 | :10 | :25 | | |
| | BTL | DTW | 1955 | 2030 | :30 | :35 | | |
| 629 | DTW | TOL | 2100 | 2120 | :10 | :20 | | |
| | TOL | FWA | 2130 | 2200 | :— | :30 | | |
| | | | Totals | | | 3:39 | 620 | 620 |

Trip 474 Freq. F&Su

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 636 | FWA | TOL | 1715 | 1745 | :10 | :30 | | |
| | TOL | PIT | 1755 | 1900 | 1:00 | 1:05 | | |
| 637 | PIT | TOL | 2000 | 2105 | :10 | 1:05 | | |
| | TOL | FWA | 2115 | 2145 | :— | :30 | | |
| | | | Totals | | | 3:10 | 530 | 530 |

Trip 475 462 Freq. F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 655 | FWA | SBN | 1725 | 1750 | :12 | :25 | | |
| | SBN | ORD* | 1802 | 1740 | 2:20 | :38 | | |
| 608 | ORD | FWA | 2000 | 2149 | :11 | :49 | | |
| | FWA | TOL | 2200 | 2230 | 11:00 | :30 | | |
| | | | Totals | | | 2:22 | 605 | 820 |
| | Airport Motel (419)865-5531 | | | | | | | |
| 33 | TOL | SBN | 0930 | 1010 | :12 | :40 | | |
| | SBN | ORD | 1022 | 1000 | 1:00 | :38 | | |
| 322 | ORD | EKI | 1100 | 1232 | :13 | :32 | | |
| | EKI | BTL | 1245 | 1307 | :38 | :22 | | |
| 323 | BTL | EKI | 1345 | 1407 | :13 | :22 | | |
| | EKI | ORD | 1420 | 1404 | 1:11 | :44 | | |
| 664 | ORD | SBN | 1515 | 1645 | :15 | :30 | | |
| | SBN | FWA | 1700 | 1725 | 1:05 | :25 | | |
| 667 | FWA | ORD | 1830 | 1825 | :45 | :55 | | |
| 508 | ORD | SBN | 1910 | 2040 | :10 | :30 | | |
| | SBN | FWA | 2050 | 2115 | :-- | :25 | | |
| | | | Totals | | | 6:03 | 1245 | 2030 |
| | | | | | | 8:25 | 1850 | 2850 |

⑪

FWA SW-4

Air Wisconsin Trip Schedule Eff. 02-15-83 thru 04-23-83

Trip 155^153^151 Freq. M-T

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 600 | FWA | DTW | 0750 | 0828 | :32 | :38 | | |
| 601 | DTW | FWA | 0900 | 0939 | :51 | :39 | | |
| 602 | FWA | DTW | 1030 | 1108 | :42 | :38 | | |
| 301 | DTW | BTL | 1150 | 1223 | 1:37 | :33 | | |
| 302 | BTL | DTW | 1400 | 1430 | :30 | :30 | | |
| 303 | DTW | BTL | 1500 | 1533 | :12 | :33 | | |
| | BTL | EKI | 1545 | 1605 | :25 | :20 | | |
| 304 | EKI | BTL | 1630 | 1650 | :10 | :20 | | |
| | BTL | DTW | 1700 | 1730 | 1:00 | :30 | | |
| 48 | DTW | CAK | 1830 | 1910 | 12:10 | :40 | | |
| | | | Totals | | | 5:21 | 1220 | 1655 |

Sheraton (219)494-6494

(10)

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 41 | CAK | DTW | 0720 | 0800 | :50 | :40 | | |
| 231 | DTW | BTL | 0850 | 0923 | :12 | :33 | | |
| | BTL | EKI | 0935 | 0955 | 1:15 | :20 | | |
| 300 | EKI | BTL | 1110 | 1130 | :10 | :20 | | |
| | BTL | DTW | 1140 | 1210 | :25 | :30 | | |
| 44 | DTW | CAK | 1235 | 1315 | :30 | :40 | | |
| 47 | CAK | DTW | 1345 | 1425 | 1:05 | :40 | | |
| 46 | DTW | CAK | 1530 | 1610 | 1:00 | :40 | | |
| 49 | CAK | DTW | 1710 | 1750 | 1:10 | :40 | | |
| 239 | DTW | BTL | 1900 | 1933 | 11:17 | :33 | | |
| | | | Totals | | | 5:36 | 1313 | 2400 |

Stouffer's (616)963-7050

(10)

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 230 | BTL | DTW | 0650 | 0720 | 1:05 | :30 | | |
| 40 | DTW | CAK | 0825 | 0905 | :45 | :40 | | |
| 43 | CAK | DTW | 0950 | 1030 | :30 | :40 | | |
| 603 | DTW | FWA | 1100 | 1139 | :51 | :39 | | |
| 620 | FWA | DTW | 1230 | 1308 | :52 | :38 | | |
| 623 | DTW | TOL | 1400 | 1420 | :25 | :20 | | |
| 734 | TOL | CLE | 1445 | 1518 | :42 | :38 | | |
| 735 | CLE | TOL | 1600 | 1632 | :28 | :32 | | |
| 736 | TOL | CLE | 1700 | 1733 | 1:27 | :33 | | |
| 737 | CLE | TOL | 1900 | 1932 | :13 | :32 | | |
| | TOL | FWA | 1945 | 2015 | :— | :30 | | |
| | | | Totals | | | 6:12 | 1425 | 2030 |
| | | | | | | 17:09 | 3958 | 6125 |

(11)

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Trip 155^154^157 Freq. W

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 600 | FWA | DTW | 0750 | 0828 | :32 | :38 | | |
| 601 | DTW | FWA | 0900 | 0939 | :21 | :39 | | |
| 602 | FWA | DTW | 1030 | 1108 | :42 | :38 | | |
| 301 | DTW | BTL | 1150 | 1223 | 1:37 | :33 | | |
| 302 | BTL | DTW | 1400 | 1430 | :30 | :30 | | |
| 303 | DTW | BTL | 1500 | 1533 | :12 | :33 | | |
| | BTL | EKI | 1545 | 1605 | :25 | :20 | | |
| 304 | EKI | BTL | 1630 | 1650 | :10 | :20 | | |
| | BTL | DTW | 1700 | 1730 | 1:00 | :30 | | |
| 48 | DTW | CAK | 1830 | 1910 | 12:10 | :40 | | |
| | | | Totals | | | 5:21 | 1220 | 1655 |

Sheraton (219)494-6494

(10)

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 41 | CAK | DTW | 0720 | 0800 | :50 | :40 | | |
| 231 | DTW | BTL | 0850 | 0923 | :12 | :33 | | |
| | BTL | EKI | 0935 | 0955 | 1:15 | :20 | | |
| 300 | EKI | BTL | 1110 | 1130 | :10 | :20 | | |
| | BTL | DTW | 1140 | 1210 | :25 | :30 | | |
| 44 | DTW | CAK | 1235 | 1315 | :30 | :40 | | |
| 47 | CAK | DTW | 1345 | 1425 | 1:05 | :40 | | |
| 46 | DTW | CAK | 1530 | 1610 | 1:00 | :40 | | |
| 49 | CAK | DTW* | 1710 | 1750 | :40 | :40 | | |
| 48 | DTW | CAK | 1830 | 1910 | 14:40 | :40 | | |
| | | | Totals | | | 5:43 | 1250 | 2400 |

Sheraton (219)494-6496

(10)

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 43 | CAK | DTW | 0950 | 1030 | :30 | :40 | | |
| 603 | DTW | FWA | 1100 | 1139 | :51 | :39 | | |
| 620 | FWA | DTW | 1230 | 1300 | :52 | :38 | | |
| 623 | DTW | TOL | 1400 | 1420 | :25 | :20 | | |
| 734 | TOL | CLE | 1445 | 1518 | :42 | :38 | | |
| 735 | CLE | TOL | 1600 | 1632 | :28 | :32 | | |
| 736 | TOL | CLE | 1700 | 1733 | 1:27 | :33 | | |
| 737 | CLE | TOL | 1900 | 1932 | :13 | :32 | | |
| | TOL | FWA | 1945 | 2015 | :-- | :30 | | |
| | | | Totals | | | 5:02 | 1125 | 2030 |
| | | | | | | 16:06 | 3635 | 6125 |

(9)

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Trip 156^161^160 Freq. Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 600 | FWA | DTW | 0750 | 0828 | :32 | :38 | | |
| 601 | DTW | FWA | 0900 | 0939 | :51 | :39 | | |
| 602 | FWA | DTW | 1030 | 1108 | :42 | :38 | | |
| 301 | DTW | BTL | 1150 | 1223 | 1:37 | :33 | | |
| 302 | BTL | DTW | 1400 | 1430 | :30 | :30 | | |
| 303 | DTW | BTL | 1500 | 1533 | :12 | :33 | | |
| | BTL | EKI | 1545 | 1605 | :25 | :20 | | |
| 304 | EKI | BTL | 1630 | 1650 | :10 | :20 | | |
| | BTL | DTW* | 1700 | 1730 | 1:30 | :30 | | |
| 239 | DTW | BTL | 1900 | 1933 | 16:07 | :33 | | |
| | | | Totals | | | 5:14 | 1243 | 1655 |

Stouffer's (616)963-7050

(10)

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 300 | BTL | DTW | 1140 | 1210 | :25 | :30 | | |
| 44 | DTW | CAK | 1235 | 1315 | :30 | :40 | | |
| 47 | CAK | DTW | 1345 | 1425 | 1:05 | :40 | | |
| 46 | DTW | CAK | 1530 | 1610 | 1:00 | :40 | | |
| 49 | CAK | DTW | 1710 | 1750 | 1:10 | :40 | | |
| 239 | DTW | BTL | 1900 | 1933 | 15:12 | :33 | | |
| | | | Totals | | | 3:43 | 853 | 2400 |

Stouffer's (616)494-6494

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 500 | BTL | DTW | 1045 | 1115 | :35 | :30 | | |
| 505 | DTW | BTL | 1150 | 1223 | :12 | :33 | | |
| | BTL | EKI | 1235 | 1255 | :20 | :20 | | |
| 502 | EKI | FWA | 1315 | 1338 | :12 | :23 | | |
| | FWA | DTW | 1350 | 1428 | :17 | :38 | | |
| 565 | DTW | FWA | 1445 | 1524 | :-- | :39 | | |
| | | | Totals | | | 3:03 | 539 | 1539 |
| | | | | | | 12:00 | 2715 | 5634 |

FWA SWY

Trip 159,158 Freq. F.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 602 | FWA | DTW | 1030 | 1108 | :42 | :38 | | |
| 301 | DTW | BTL | 1150 | 1223 | 1:37 | :33 | | |
| 302 | BTL | DTW | 1400 | 1430 | :30 | :30 | | |
| 303 | DTW | BTL | 1500 | 1533 | :12 | :33 | | |
| | BTL | EKI | 1545 | 1605 | :25 | :20 | | |
| 304 | EKI | BTL | 1630 | 1650 | :10 | :20 | | |
| | BTL | DTW | 1700 | 1730 | 1:00 | :30 | | |
| 48 | DTW | CAK | 1830 | 1910 | 14:40 | :40 | | |
| | | | Totals | | | 4:04 | 940 | 1415 |

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Sheraton (219)494-6494

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 43 | CAK | DTW | 0950 | 1030 | :30 | :40 | | |
| 603 | DTW | FWA | 1100 | 1139 | :— | :39 | | |
| | | | Totals | | | 1:19 | 249 | 1154 |
| | | | | | | 5:23 | 1229 | 2609 |

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Trip 162 Freq. M-F

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 620 | FWA | DTW | 1230 | 1308 | :52 | :38 | | |
| 623 | DTW | TOL | 1400 | 1420 | :25 | :20 | | |
| 734 | TOL | CLE | 1445 | 1518 | :42 | :38 | | |
| 735 | CLE | TOL | 1600 | 1632 | :28 | :32 | | |
| 736 | TOL | CLE | 1700 | 1733 | 1:27 | :33 | | |
| 737 | CLE | TOL | 1900 | 1932 | :13 | :32 | | |
| | TOL | FWA | 1945 | 2015 | :— | :30 | | |
| | | | Totals | | | 3:43 | 845 | 845 |

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Trip 163,153,151 Freq. Su.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 620 | FWA | DTW | 1230 | 1308 | 2:22 | :38 | | |
| 46 | DTW | CAK | 1530 | 1610 | 1:00 | :40 | | |
| 49 | CAK | DTW | 1710 | 1750 | :40 | :40 | | |
| 48 | DTW | CAK | 1830 | 1910 | 12:10 | :40 | | |
| | | | Totals | | | 2:38 | 740 | 1215 |

Sheraton (219)494-6494

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 41 | CAK | DTW | 0720 | 0800 | :50 | :40 | | |
| 231 | DTW | BTL | 0850 | 0923 | :12 | :33 | | |
| | BTL | EKI | 0935 | 0955 | 1:15 | :20 | | |
| 300 | EKI | BTL | 1110 | 1130 | :10 | :20 | | |
| | BTL | DTW | 1140 | 1210 | :25 | :30 | | |
| 44 | DTW | CAK | 1235 | 1315 | :30 | :40 | | |
| 47 | CAK | DTW | 1345 | 1425 | 1:05 | :40 | | |
| 46 | DTW | CAK | 1530 | 1610 | 1:00 | :40 | | |
| 49 | CAK | DTW | 1710 | 1750 | 1:10 | :40 | | |
| 239 | DTW | BTL | 1900 | 1933 | 11:17 | :33 | | |
| | | | Totals | | | 5:36 | 1313 | 1948 |

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Stouffer's (616)963-7050

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 230 | BTL | DTW | 0650 | 0720 | 1:05 | :30 | | |
| 40 | DTW | CAK | 0825 | 0905 | :45 | :40 | | |
| 43 | CAK | DTW | 0950 | 1030 | :30 | :40 | | |
| 603 | DTW | FWA | 1100 | 1139 | :51 | :39 | | |
| 620 | FWA | DTW | 1230 | 1308 | :52 | :38 | | |
| 623 | DTW | TOL | 1400 | 1420 | :25 | :20 | | |
| 734 | TOL | CLE | 1445 | 1518 | :42 | :38 | | |
| 735 | CLE | TOL | 1600 | 1632 | :28 | :32 | | |
| 736 | TOL | CLE | 1700 | 1733 | 1:27 | :33 | | |
| 737 | CLE | TOL | 1900 | 1932 | :13 | :32 | | |
| | TOL | FWA | 1945 | 2015 | :-- | :30 | | |
| | | | Totals | | | 6:12 | 1425 | 2030 |
| | | | | | | 14:26 | 3518 | 5233 |

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Trip 164 151 Freq. Su.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 302 | FWA | BTL | 1325 | 1350 | :10 | :25 | | |
| | BTL | DTW | 1400 | 1430 | :15 | :30 | | |
| 565 | DTW | FWA | 1445 | 1524 | :10 | :39 | | |
| | FWA | EKI | 1535 | 1558 | :32 | :23 | | |
| 304 | EKI | BTL | 1630 | 1650 | :10 | :20 | | |
| | BTL | DTW | 1700 | 1730 | 1:30 | :30 | | |
| 239 | DTW | BTL | 1900 | 1933 | 11:17 | :33 | | |
| | | | Totals | | | 3:20 | 708 | 1120 |

Stouffer's (616)963-7050

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 230 | BTL | DTW | 0650 | 0720 | 1:05 | :30 | | |
| 40 | DTW | CAK | 0825 | 0905 | :45 | :40 | | |
| 43 | CAK | DTW | 0950 | 1030 | :30 | :40 | | |
| 603 | DTW | FWA | 1100 | 1139 | :51 | :39 | | |
| 620 | FWA | DTW | 1230 | 1308 | :52 | :38 | | |
| 623 | DTW | TOL | 1400 | 1420 | :25 | :20 | | |
| 734 | TOL | CLE | 1445 | 1518 | :42 | :38 | | |
| 735 | CLE | TOL | 1600 | 1632 | :28 | :32 | | |
| 736 | TOL | CLE | 1700 | 1733 | 1:27 | :33 | | |
| 737 | CLE | TOL | 1900 | 1932 | :13 | :32 | | |
| | TOL | FWA | 1945 | 2015 | :-- | :30 | | |
| | | | Totals | | | 6:12 | 1425 | 2030 |
| | | | | | | 9:32 | 2133 | 3150 |

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Trip 165 Freq. Su.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 734 | FWA | TOL | 1405 | 1435 | :10 | :30 | | |
| | TOL | CLE | 1445 | 1518 | :42 | :38 | | |
| 735 | CLE | TOL | 1600 | 1632 | :28 | :32 | | |
| 736 | TOL | CLE | 1700 | 1733 | 1:27 | :33 | | |
| 737 | CLE | TOL | 1900 | 1932 | :13 | :32 | | |
| | TOL | FWA | 1945 | 2015 | :-- | :30 | | |
| | | | Totals | | | 3:15 | 710 | 710 |

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Trip 152 Freq. M-Th.

| Flt | Dpt | Arv | Dptr | Arvl | L/O | Blk | DTm | THr |
|---|---|---|---|---|---|---|---|---|
| 230 | BTL | DTW | 0650 | 0720 | 1:05 | :30 | | |
| 40 | DTW | CAK | 0825 | 0905 | :45 | :40 | | |
| 43 | CAK | DTW | 0950 | 1030 | :30 | :40 | | |
| 603 | DTW | FWA | 1100 | 1139 | :-- | :39 | | |
| | | | Totals | | | 2:39 | 549 | 1154 |

Attachment #6

ENGINEERING DEPARTMENT
RECEIVED
FEB 03 1983

Box 354-A RD#2
Douglassville, PA 19518
January 31, 1983

Mr. Ray Young
Engineering and Air Safety
Air Line Pilots Association
1625 Massachusetts Ave., N.W.
Washington, D.C. 20036

Dear Mr. Young:

Enclosed are the block alignments for the three domiciles operated by Suburban Airlines. Currently the most landings is eight. In past months we have had trips with as many as ten landings. Unfortunately it is lower traffic and not management's concern ~~concern~~ for pilot fatigue that has resulted in fewer landings per block. An increase in traffic could possibly bring the return of blocks with ten landings. I hope this information will be useful to you and if I can further assist you please do not hesitate to contact me.

Sincerely yours,

7 segments of 30 require
8 or more landings

Stephen S. Loose
Vice-Chairmen
Suburban Council #78

## READING BLOCK ALIGNMENTS 01 FEB 1983

RA BLOCK - 0555 to 1220 = 6.4 Duty/3.0 Block 1 only 6 LANDINGS

1151 - RDG-PHL-RDG
1152 - RDG-PHL-RDG
1153 - RDG-PHL-RDG

RC BLOCK - 1138 to 1740 = 6.0 Duty/3.0 Block 1 only 6 LANDINGS

1154 - RDG-PHL-RDG
1155 - RDG-PHL-RDG
1156 - RDG-PHL-RDG

RE BLOCK - 1700 to 2310 = 6.2 Duty/3.0 Block 1-7 only 6 LANDINGS

1157 - RDG-PHL-RDG
1158 - RDG-PHL-RDG
1159 - RDG-PHL-RDG

RB BLOCK - 0555 to 1550 = 9.9 Duty/4.0 Block x 1 6 7 8 LANDINGS

1151 - RDG-PHL-RDG
1152 - RDG-PHL-RDG
1154 - RDG-PHL-RDG
1155 - RDG-PHL-RDG

RD BLOCK - 1508 to 2310 = 8.0 Duty/4.0 Block x 1 6 7 8 LANDINGS

1156 - RDG-PHL-RDG
1157 - RDG-PHL-RDG
1158 - RDG-LNS-PHL
1159 - RDG-PHL-RDG

RS BLOCK - 0745 to 1740 = 9.9 Duty/3.0 Block 6 only 6 LANDINGS

1152 - RDG-PHL-RDG
1154 - RDG-PHL-RDG
1155 - RDG-PHL
1156 - PHL-RDG

RF BLOCK - 0945 to 1740 = 7.9 Duty/4.0 Block 7 only 8 LANDINGS

1153 - RDG-PHL-RDG
1154 - RDG-PHL-RDG
1155 - RDG-PHL-RDG
1156 - RDG-PHL-RDG

LANCASTER BLOCK ALIGNMENTS 1 FEB 83

LA BLOCK - 0605 to 1349 = 7.7 Duty/3.0 Block x6 7 6 LANDINGS

1169 - LNS-PHL-LNS
1168 - LNS-PHL-LNS
1167 - LNS-PHL-LNS - DHC-6

LC BLOCK - 1309 to 2215 = 9.1 Duty/4.0 Block X6 8 LANDINGS

1165 - LNS-PHL-LNS
1161 - LNS-PHL-LNS
1162 - LNS-PHL-LNS
1163 - LNS-PHL
1164 - [illegible]-PHL-LNS

LB BLOCK (DHC-6) - 0615 to 0945 = 3.5 Duty/2.0 Block X6 7 4 LANDINGS

1171 - LNS-RDG-EWR
1172 - EWR-RDG-LNS

LD BLOCK (DHC-6) - 1340 to 2025 = 6.8 Duty/4.3 Block x6 7 8 LANDINGS

1173 - LNS-ABE-JFK
1174 - JFK-ABE-LNS
1175 - LNS-RDG-EWR
1176 - EWR-RDG-LNS

LS BLOCK - 0800 to 1745 = 9.8 Duty/3.0 Block 6 only 6 LANDINGS

1168 - LNS-PHL-LNS
1167 - LNS-PHL-LNS - DHC-6
1166 - LNS-PHL
1161 - PHL-LNS

LG BLOCK (DHC-6) - 1340 to 1735 = 3.9 Duty/2.3 Block 6 only 4 LANDINGS

1173 - LNS-ABE-JFK
1174 - JFK-ABE-LNS

LF BLOCK - 1123 to 1735 = 4.2 Duty/3.3 Block 7 only 6 LANDINGS

1167 - LNS-PHL-LNS - DHC-6
1173 - LNS-ABE-JFK - DHC-6
1174 - JFK-ABE-LNS - DHC-6

FLIGHT ATTENDANTS ONLY

LH BLOCK - 0605 to 1040 = 4.7 Duty/2.0 Block x6 7

1169 - LNS-PHL-LNS
1168 - LNS-PHL-LNS

ABE BLOCK ALIGNMENTS 01 FEB 1983

x 6 7 AA - 0550 to 1635 = 10.7 Duty/4.4 Block
1105, 1106 (ABE-PHL), 1126, 1127 D.H. 1109 (PHL-ABE) 7 LANDINGS + DEAD HEAD

x 6 7 AC - 0610 to 1440 = 8.5 Duty/4.7 Block
1100, 1101, 1103 (JFK-ABE) 6 LANDINGS

x 6 7 AJ - 1345 to 2105 = 7.3 Duty/4.7 Block
1103 (ABE-BUF), 1104, 1177 6 LANDINGS

x 6 7 AI - 1150 to 2055 = 9.1 Duty/2.9 Block
1108, 1109, D.H. 1114 (ABE-PHL), 1124 5 LANDINGS + DEAD HEAD

x 6 7 IA - 0635 to 1635 = 10.0 Duty/2.7 Block
1119, 1121, D.H. 1109 (PHL-ABE) 3 LANDINGS + DEAD HEAD

x 6 7 GA - 0555 to 1240 = 6.7 Duty/3.0 Block
1125, 1106 (PHL-ABE), 1107 5 LANDINGS

x 6 GC - 1205 to 2135 = 9.5 Duty/4.3 Block
D.H. 1108 (ABE-PHL), 1128, 1129, 1130 6 LANDINGS + DEAD HEAD

x 6 AE - 1540 to 2315 = 7.6 Duty/4.0 Block
1114, 1115, 1116, 1117 8 LANDINGS

6 only GG - 0930 to 1805 = 8.6 Duty/2.8 Block
1131, 1134 4 LANDINGS

6 only AS - 0750 to 1730 = 9.7 Duty/2.5 Block
1106, 1107, 1108 (ABE-PHL), D.H. 1134 (PHL-ISP) 5 LANDINGS + DEAD HEAD

6 only IS - 1010 to 1815 = 8.1 Duty/2.5 Block
D.H. 1131 (ISP-PHL), 1108 (PHL-ABE), 1109, 1114 5 LANDINGS + DEAD HEAD

7 only AI - 1345 to 2055 = 7.2 Duty/1.9 Block
1109, D.H. 1114 (ABE-PHL), 1124 3 LANDINGS + DEAD HEAD

7 only AD - 1135 to 2105 = 9.5 Duty/6.3 Block
1118, 1103, 1104, 1177 8 LANDINGS

7 only SI - 1340 to 1635 = 2.9 Duty/.8 Block
1121, D.H. 1109 (PHL-ABE) 1 LANDING + DEAD HEAD

7 only GP - 1140 to 1635 = 4.9 Duty/1.4 Block
1127, D.H. 1109 (PHL-ABE) 2 LANDINGS + DEAD HEAD

7 only SP - 1005 to 1440 = 4.6 Duty/2.0 Block
1107, 1108 4 LANDINGS

Attachment

Ray Young

FROM THE DESK OF
D. J. WALDMANN
ENGINEERING DEPT.

RECEIVED
FEB 01 1983

Ray -

The 200 series flights are between Denver and Colorado Springs (even #'s north odd #'s south). The 400 series are Denver - Aspen (odd west, even east) and flight 451 continues to Rifle. flight 408 originates in Rifle and stops in Aspen. The 500 series are Aspen LAX. The westbound leg normally stops in Grand Junction for fuel. I have made notations as to the # of landings. Hope this is what you needed.

Dan

WALDMANN

INTEROFFICE CORRESPONDENCE

ASPEN

FROM Gary B. Hickman TO All Denver Pilots
ADDRESS ADDRESS
SUBJECT: February 1983 DATE 1-18-83 COPIES

Attached, are the line awards for February. I've also attached the list of "open time" which I provided with the initial bids.

There is some additional "open time" which is due to training requirements. That time has been added to the end of the list.

The training dates have been rescheduled. They are as follows:

February 2 & 3 Ground School and PC
Rosanbalm
Krasovich

February 22 & 23 Ground School only
Mattson
G. Sims

The secondary bid opens today 1/18 and closes on 1/23 at 1400 MST. Awards will be made the following day.

You may bid single flights i.e. a round trip to ASE or COS, or you can bid as many flights on the same day as the FAR's will permit.

A bid form is attached. I must insist you submit your bids in writing.

Gary B. Hickman

Gary B. Hickman
Manager, Operations Planning

GBH/br

Attachment

Flights with 8 or more landings

| | |
|---|---|
| Mon | 3 of 5 - 9 |
| Tue-Wed | 3 of 4 - 9 |
| Thur | 2 of 5 - 9 |
| Fri | 2 of 7 - 10 |
| | 1 of 7 - 9 |
| | 1 of 7 - 8 |
| Sat | 2 of 8 - 9 |
| | 4 of 8 - 8 |
| Sun | 2 of 7 - 9 |
| | 1 of 7 - 8 |
| TOTAL | 21 of 65 |

## PILOT BLOCKS

**MONDAY**

| | | | | | # of Landings |
|---|---|---|---|---|---|
| A | 0545-1820 | 5+25 | 12+35 | 200 415/418 425/428 435/438 445/448 | 9 |
| B | 0615-1905 | 3+50 | 12+50 | 408 201/204 205/208 209/212 213 RON COS | 9 |
| C | 0740-1705 | 4+20 | 9+25 | 412 419/422 429/432 441/444 | 7 |
| D | 0830-1945 | 4+05 | 11+15 | 404 421/424 431/434 451 RON RIL | 7 |
| E | 0920-2145 | 4+00 | 12+25 | 203/206 207/210 211/214 215/216 459 RON ASE | 9 |

**TUESDAY & WEDNESDAY**

| | | | | | |
|---|---|---|---|---|---|
| A | 0545-1705 | 5+25 | 11+20 | 200 407/412 419/422 431/434 441/444 | 9 |
| B | 0615-1905 | 3+50 | 12+50 | 408 201/204 205/208 209/212 213 RON COS | 9 |
| C | 0830-1945 | 4+05 | 11+15 | 404 425/428 435/438 451 RON RIL | 7 |
| D | 0920-2145 | 4+00 | 12+25 | 203/206 207/210 211/214 215/216 459 RON ASE | 9 |

**THURSDAY**

| | | | | | |
|---|---|---|---|---|---|
| A | 0545-1705 | 5+25 | 11+20 | 200 407/412 419/422 429/432 441/444 | 9 |
| B | 0615-1905 | 3+50 | 12+50 | 408 201/204 205/208 209/212 213 RON COS | 9 |
| C | 0830-1945 | 4+05 | 11+15 | 404 425/428 435/438 451 RON RIL | 7 |
| D | 0920-2145 | 4+00 | 12+25 | 203/206 431/434 445/448 459/ RON ASE | 7 |
| E | 1215-2155 | 2+55 | 9+40 | 207/210 211/214 215/216 217 RON COS | 7 |

**FRIDAY**

| | | | | | |
|---|---|---|---|---|---|
| A | 0545-1635 | 5+25 | 10+50 | 200 407/412 419/422 429/432 439/442 | 9 |
| B | 0615-1900 | 5+55 | 12+45 | 408 415/418 425/428 433/436 447/450 | 10 |
| C | 0830-2055 | 3+45 | 12+25 | 404 421/424 437/440 457 RON ASE | 6 |
| D | 0739-1905 | 4+10 | 11+26 | 202 201/204 205/208 209/212 211/214 213 RON COS | 10 |
| E | 0920-1945 | 3+55 | 10+25 | 203/206 207/210 441/444 451 RON RIL | 8 |
| F | 1200-2145 | 4+00 | 9+45 | 431/434 445/448 215/216 459 RON ASE | 7 |
| G | 1315-2220 | 6+55 | 9+05 | 435 503/504 462 | 5 |

# PILOT BLOCKS

## SATURDAYS

| | | | | | |
|---|---|---|---|---|---|
| A | 0545-1745 | 5+25 | 12+00 | 200 407/412 417/420 431/434 443/446 | 9 |
| B | 0615-1705 | 4+40 | 10+50 | 408 415/418 429/432 441/444 | 8 |
| C | 0615-1635 | 4+35 | 10+20 | 405/410 201/204 427/430 439/442 | 8 |
| D | 0630-1605 | 4+25 | 9+35 | 406 411/416 425/428 437/440 211/214 | 9 |
| E | 0700-1900 | 4+35 | 12+00 | 409/414 419/422 209/210 447/450 | 8 |
| F | 0545-1820 | 5+00 | 12+35 | 403/404 421/424 435/438 445/448 | 8 |
| → G | 1005-2055 | 3+45 | 10+50 | 402 433/436 449/452 457 RON ASE | 6 |
| H | 1815-2145 | 1+55 | 3+30 | 453/456 459 RON ASE | 3 |

## SUNDAYS

| | | | | | |
|---|---|---|---|---|---|
| A | 0630-1820 | 5+40 | 11+50 | 406 411/416 421/424 433/436 445/448 | 9 |
| B | 0630-1605 | 5+00 | 9+35 | 407/412 417/420 427/430 437/440 | 8 |
| C | 0650-1900 | 5+40 | 12+10 | 408 415/418 425/428 435/438 447/450 | 9 |
| D | 0700-1945 | 4+05 | 12+45 | 409/414 419/422 431 DH to DEN 451 RON RIL | 7 |
| E | 0835-1905 | 2+55 | 10+30 | 201/204 209/210 211/214 213 RON COS | 7 |
| F | 1130-2145 | 4+00 | 10+15 | 429/432 441/444 215/216 459 RON ASE | 7 |
| G | 1200-2015 | 5+40 | 8+15 | 501/500 RON ASE | 3 |

PILOTS

FEBRUARY '83

CAPTAINS

CREW SCHEDULE

| | | BORQUIST | BARNUSKI | HAYNES | LANCASTER | CARTIGEE | COBLE | KRASOVICH | WALDMANN | G. DAVIS | SMITH | FORSTER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 31 | C | A | B | D | E | | | | | | | | |
| | 1 | | | A | B | C | D | | | | | | | |
| W | 2 | | | | A | B | C | TR | | | | | | |
| | 3 | | | | | A | B | TR | D | E | | | | |
| | 4 | G | | | | | B | B<br>4/15(a) | C | D | A | F | | |
| S | 5 | H | E | C | F | | | | D | A | B | G | | |
| S | 6 | C | E | B | E | G | | D | | | | A | | |
| | 7 | | B | | C | D | F | B | | | | | | |
| | 8 | | | | | B | C | B | D | | | | | |
| W | 9 | | | | | A | B | | C | D | | | | |
| | 10 | | | | | | B | | B | C | D | B | | |
| | 11 | E | E | | G | | | | A | B | C | D | | |
| S | 12 | G | B | E | H | | | F | C | | D | A | | |
| S | 13 | B | D | E | C | B | | E | | G | | | | |
| | 14 | | B | B | | F | | C | | D | | | | |
| | 15 | | B | | | C | D | | | B | | | | |
| W | 16 | | | | | B | C | | | B | D | | | |
| | 17 | | | | | B | B | | E | | C | D | | |
| | 18 | E | | G | F | | B | | D | | B | C | | |
| S | 19 | B | F | H | G | | C | E | B | | | D | | |
| S | 20 | D | E | C | B | | | B | | | G | B | | |
| | 21 | B | C | | | | | B | | E | D | | | |
| | 22 | B | | | | | | | | C | B | D | | |
| W | 23 | | | | | | | | D | B | B | C | | |
| | 24 | | | | | F | D | | C | B | | B | | |
| | 25 | | F | E | G | D | C | | B | | | A | | |
| S | 26 | E | G | B | H | B | D | E | | | | C | | |
| S | 27 | E | B | D | C | | | E | | G | B | | | |
| | 28 | B | | B | | | | C | | D | E | | | |
| MAR | 1 | | | B | | | | | D | B | C | | | |
| FLT | | 67+05 | 67+00 | 69+10 | 69+05 | 71+10 | 69+45 | 64+55 | 64+35 | 76+25 | 66+10 | 65+00 | | |
| DUTY | | 179+50 | 170+30 | 162+05 | 150+50 | 172+01 | 177+15 | 173+45 | 174+01 | 193+01 | 169+00 | 187+11 | | |

PILOTS

FEBRUARY '83

CAPTAINS

CREW SCHEDULE

| | | KIRWAN | ROSENBAUM | MOORE | KINDER |
|---|---|---|---|---|---|
| JAN | 31 | | R | R | R |
| | 1 | | R | R | R |
| W | 2 | | TR | R | R |
| | 3 | R | TR | | R |
| | 4 | R | m | R | |
| S | 5 | m | R | R | |
| S | 6 | R | | R | R |
| | 7 | R | | R | m |
| | 8 | | | R | R |
| W | 9 | | R | | R |
| | 10 | R | | R | R |
| | 11 | R | | R | R |
| S | 12 | | R | R | R |
| S | 13 | R | m | R | |
| | 14 | R | R | m | |
| | 15 | R | R | | |
| W | 16 | R | R | | R |
| | 17 | R | R | | R |
| | 18 | R | | R | R |
| S | 19 | | R | R | R |
| S | 20 | R | R | m | m |
| | 21 | R | R | | m |
| | 22 | R | R | m | R |
| W | 23 | R | | R | m |
| | 24 | m | R | m | |
| | 25 | R | m | V R | |
| S | 26 | m | R | A R | R |
| S | 27 | R | m | C R | R |
| | 28 | R | R | m | R |
| MAR | 1 | m | R | R | R |
| | 2 | | | | |
| | 3 | | | | |

Attachment #8

# Pilot Fatigue Study: A First Look

By Captain Harris E. Dexter (WAL), Member, ALPA Aeromedical Committee

What causes pilot fatigue? To find what the ALPA membership feels are the areas that may have significance in contributing to fatigue, the Aeromedical Committee sent an exhaustive questionnaire to all member pilots.

In seeking this information, the Committee hoped to obtain the data for an in-depth scientific look at airline pilot fatigue and the interrelationships of flight-time/duty-time rules, cockpit environment and duty rigs.

The questionnaire contained 169 queries, which with subparts totaled over 400 questions, with some questions having as many as 15 possible answers. Despite its great length, about 50% of the ALPA membership completed the questionnaire. In addition, many pilots attached lengthy letters or flight schedules as substantiating data to their replies.

The length of the questionnaire made its analysis a complex affair that required the use of innovative statistical techniques.

Captains accounted for 40% of the survey's respondents, first officers for 38% and second officers for 25% (figures were rounded to nearest percentage point). Of total respondents 94.5% were active line pilots; 3% were check airmen; 1.6% were instructor pilots, and 0.4% each were navigators or in management. (ALPA at the time of the survey did not represent second officers on all carriers and some airlines do not have second officers. This accounts for second officer responses amounting to less than an equal distribution among the three major categories of flight officers.)

Respondents indicated that 76% of their last flight or series of flights had been domestic; 15% were international; and 9% were domestic and international, which were under different flight-time/duty-time provisions of the Federal Aviation Regulations.

On the basis of home domicile time, 64% of most of the above flights occurred between 8 a.m. and 7 p.m., 23% between 7 p.m. and 1 a.m. and 13% between 1 and 8 a.m.

From the time pilots leave their home domicile until the time they return, the number of landings made range from one to 24 in a trip sequence, with 50% of the pilots making six or fewer landings and 50% making seven or more. The mean number of landings is 6.25. (In some cases, pilots counted only landings made themselves and not the number of landings made by the entire crew and aircraft. In addition, this question can be interpreted several ways because of different interpretations of trip sequence. The Aeromedical Committee believes this question is closely related to others in the questionnaire and, therefore, subject to additional interpretation.)

Flight deck crew size ranged from two to six crew members: two, 19%; three, 78%; four, 2%; and five, 1%.

Does the trip from home to work contribute to fatigue? Most pilots live in easy commuting distances from their assigned bases: more than 66% live within an hour of their base and more than 86% are within two hours. Less than 16% feel that travel from home to work contributes to fatigue.

One-hour flight planning is adequate in the view of 69% of the crew members, while 27% feel that 60 to 90 minutes is the proper amount of time for reporting on duty before flight departure. The 27% asking for the additional time were mainly pilots who fly international routes, where longer periods of preflight planning are necessary.

In the previous 30 days of flying, 34% of the respondents were on reserve duty (standing by the telephone). Of the 34%, half had been on reserve between two and three weeks, 22% between three weeks and one month, and 20% were on call up to two weeks.

Regarding notice given before flight departure, 38% of the reserves received less than six hours' notice and 92% received less than 24 hours' notice. Less than one hours' notice was the shortest by 28%, while 56% received notices ranging between one and five hours prior to trip departure.

What may be regarded as short or inadequate notice prior to trip departure, therefore, was reported by 84% of the survey's reserves.

Company policy, according to 53% of the reserves, does not allow crew members to leave home while on reserve for several hours at a time to transact personal business.

In addition, 34% said their companies interpret the Federal Aviation Regulations to consider a day on call by the phone as a day off to fulfill the FARs' "one day's rest in seven."

The Aeromedical Committee believes that the FARs "in no way allow a day of reserve to be counted as a day of rest." The survey helped to determine which companies have policies that allow a retrospective calculation of a day on reserve to be credited as a day of rest.

About the reserve duty problem the committee said: ". . . it is entirely improper that any segment of the aviation industry should be permitted to interpret the regulations in such a way as to require a crew member to be on duty and available every moment of a 24-hour reserve period, and to require a pilot to fly without an opportunity to adjust biological rhythms to such requirements.

"We feel that these regulations should not be written so that such interpretations can be construed.

Current regulations not only allow a man to be required to be on duty for a 24-hour period of time on an on-call basis, but also allow on-duty requirements to be extended over a period of six days.

"Furthermore, retroactive calculations of these days as a day off can then result in the companies requiring another six days, and so on indefinitely, of on-duty activity on reserve. The results of this questionnaire lead us to believe that this is a major safety item."

Preflight services are considered adequate by 76% of the respondents. Of the 24% who consider them inadequate, about one-third are unhappy with weather services, while two-thirds cite inadequate planning services and/or poor communications with dispatchers.

Trip delays are rated as a contributing factor to fatigue by 98%. Crew members, however, are least irritated by delays over which they have no control, such as the weather. Matters that can be controlled by improved management, such as mechanical delays or passenger service delays, are major irritants (91%).

### Flight Vs. Duty Time

More than 66% of the respondents were scheduled for on-duty time of more than eight and less than 13 hours in their most recent duty period. Actual on-duty time was close to scheduled time, however, 7% were on duty 14 hours or more.

About one half of the pilots feel that FARs regarding flight-time/duty-time are realistic, but 65% still feel they should be changed. Of those who feel changes are necessary, 87% say they are needed to reduce pilot fatique; 76% say revisions are needed for safety reasons; 47% say changes are needed to increase the productive flying years of airline pilots.

According to 87%, the FARs should be rewritten to accommodate different types of flying: multiple landings, multiple time zones, night operations, duration of flight and international flights.

Maximum number of hours a pilot can stay on duty before becoming inefficient varies according to time of day and weather conditions: day vs. night and VFR vs. IFR. During daytime VFR operations, most pilots believe they can stay on duty 10-12 hours before they lose their efficiency. In IFR daytime operations, most pilots feel they become inefficient after being on duty 8-10 hours. In both VFR-night and IFR-night operations the figures drop to 6-8 hours, with a greater percentage of pilots saying 4-6 hours should be the maximum for IFR-night.

During their last one day's work, 81% of the pilots said they had made one to seven landings; while 19% made more than seven landings, with some reporting as many as 18 to 20.

How many landings do pilots feel they can make during one duty day and still remain safe and efficient? Under VFR-daytime conditions, 58% say they can make up to six landings; 83% feel they can make a maximum of six landings in day-night operations; 81% say that six landings are the maximum in IFR-day and 88% feel that six landings are the maximum in IFR-night.

To the question "Is fatigue a problem in your type of airline flying?" 93% said, yes. In the view of 98% of the pilots, they are generally able to determine when fatigue is affecting their performance, and 85% say they did feel extremely tired, or washed out, at least once during a flight or immediately afterward in the past 30 days of flying.

If one of four areas were to be given more credit (or weight) towards total flight hours, 38% say it should be given to night flying (back of the clock), 29% think it should go to long duty periods, 23% feel multiple landings should be favored and 10% say multiple time zone flights.

When the results are broken out from a major international carrier, however, the ranking is markedly different: 45% of international pilots opt for multiple time zone flights; 26% choose long duty periods, 22% check night flying (back of the clock), and only 6% select multiple landings.

### Jet Lag

Of pilots whose flights span three or more time zones, 60% say they adjust their life style to a new time zone and 40% keep their life style associated with the home domicile.

Of the pilots who adjust to a new time zone, one-third say the adjustment is difficult with regard to sleep; another third say it is difficult sometimes, 8% have no difficulty adjusting, and 25% say it does not apply.

Adjusting to a new time zone requires one day according to 35%, two days 44%, three days 16%, four days 2% and more than four days 3%.

The most important factor in determining the minimum rest break is the length of on-duty period before the rest break, according to 60%; length of on-duty time after the rest break is the most important factor to 27%; number of landings is most important to 7% and length of the flight is the factor for 6%.

After completing a duty period away from the home domicile, 42% of the pilots believe they should have a minimum of 12 hours off between duty periods and 66% feel that between 12 and 16 hours are necessary. About 70% believe the maximum rest period should be between 16 and 24 hours.

The Aeromedical Committee, however, believes the survey shows that rest-period length should be geared with the type of flying involved and the amount of flying both preceding and scheduled to follow the rest period. For example, crew members on international, around-the-world operations would be flying as much as 10 to 12 days in a row. These pilots feel that once or twice during the operation, two or three days of rest should be provided so they can recoup for the remainder of the trip sequence.

Based on the schedules they flew in the past 30-day period, none of the pilots think they should fly 80-85 hours a month; 9% chose 50-55 hours; 15%—55-60 hours; 21%—60-65 hours; 40%—65-70 hours; 11%—70-75 hours; and 4%—75-80 hours.

Approximately 80% of the crew members prefer duty period-days off patterns either between two days on, two days off, and four days on, four days off; however 14% choose six days on, six days off.

Preferred work-days-off patterns, however, are influenced by many differences among the airlines and types of flying. For extended international operations away from home, the figures are much higher for the longer day on-day off patterns.

The ALPA fatigue study has been broken into 28 categories for ease in analyzing. Pertinent results will be published in future issues of *Air Line Pilot*. ☐

SA-397

JAN 28 1968

Attachment #9
File 1-0003

# AIRCRAFT ACCIDENT REPORT

Adopted: December 20, 1967

DELTA AIR LINES, INC.
DC-8, N802E
Kenner, Louisiana
March 30, 1967

NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
WASHINGTON D.C. 20591

### 1.5 Crew Information

Captain Maurice G. Watson, age 44, held airline transport pilot certificate No. 283056 with ratings for DC-3, DC-6/7, DC-8, DC-9, CV 240/340/440, and airplane multiengine land with commercial privileges in single-engine land and sea. He was hired on June 3, 1949, and had accumulated 19,008 total flying hours of which 58 hours were as captain and 417 hours as first officer in the DC-8. His total flight time in the last 30 days, 42 hours, was accomplished at night in the DC-8. He was a company-designated DC-9 check airman and received FAA approval of his DC-8 check airman designation on December 30, 1966. His last proficiency check was completed on December 16, 1966, and an FAA first-class medical certificate was issued on December 20, 1966, with no limitations. He had been on duty 3:20 hours in the last 24-hour period and was the instructor pilot on this flight.

Captain James W. Morton, age 48,[3] held airline transport pilot certificate No. 186568 with ratings for DC-3, DC-6/7, DC-9, CV 240/340/440 and airplane multiengine land with commercial privileges in single-engine land. He was hired on March 13, 1951, and had accumulated 16,929 total flying hours of which 15 hours were in the DC-8. The DC-8 time was all accomplished at night, and represented his total flying time for the preceding 30-day period. His last proficiency check was conducted on September 21, 1966, in DC-9 equipment. His FAA first-class medical certificate was issued January 27, 1967, with the following restriction, "Defective near vision - holder shall possess correcting glasses while exercising privileges of his airman certificate."

---

[3] Although Captain Morton's airman records contained two birth dates, a review of other records revealed his birth date as April 17, 1918.

travel, meals, bathing, dressing, and other personal activities in addition to study for the training flights it is obvious that his actual rest was minimal. Although fatigue and its effects are subjective in nature and difficult to assess, the disturbed work-rest cycle superimposed on the natural stresses of the training environment was undoubtedly reflected in the performance of the captain-trainee.

## 2.2 Conclusions

### (a) Findings

1. The aircraft was airworthy and the crew properly certificated.
2. There was no failure of any aircraft system, powerplant or component.
3. The captain-trainee was performing a simulated two-engine out landing maneuver.
4. The captain-trainee's performance was affected by some degree of fatigue.
5. The instructor lowered full landing flaps, on his own initiative, too early in the approach.
6. The instructor failed to assume control of the aircraft despite the rapidly deteriorating circumstances.
7. The instructor's actions were affected by his confidence in in the captain-trainee's ability.

Attachment #10

# NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

# AIRCRAFT ACCIDENT REPORT

## AIR NEW ENGLAND, INC.
## DeHAVILLAND DHC-6-300, N383 EX
## HYANNIS, MASSACHUSETTS
## JUNE 17, 1979

NTSB-AAR-80-1

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

| | | |
|---|---|---|
| 1. Report No.<br>NTSB-AAR-80-1 | 2.Government Accession No. | 3.Recipient's Catalog No. |
| 4. Title and Subtitle<br>Aircraft Accident Report - Air New England, Inc., deHavilland DHC-6-300, N383EX, Hyannis, Massachusetts, June 17, 1979 | | 5.Report Date<br>January 3, 1980 |
| | | 6.Performing Organization Code |
| 7. Author(s) | | 8.Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>National Transportation Safety Board<br>Bureau of Accident Investigation<br>Washington, D.C. 20594 | | 10.Work Unit No.<br>2704A |
| | | 11.Contract or Grant No. |
| 12.Sponsoring Agency Name and Address<br>NATIONAL TRANSPORTATION SAFETY BOARD<br>Washington, D. C. 20594 | | 13.Type of Report and Period Covered<br>Aircraft Accident Report<br>June 17, 1979 |
| | | 14.Sponsoring Agency Code |
| 15.Supplementary Notes | | |

16.Abstract

About 2248 e.d.t., on June 17, 1979, Air New England, Inc., Flight 248 crashed into a heavily wooded area about 1.5 nmi northeast of Barnstable Municipal Airport, Hyannis, Massachusetts. The crash occurred during an instrument landing system approach to runway 24 in instrument meteorological conditions. Of the eight passengers and a crew of two aboard, the captain was killed, the first officer and six passengers were injured seriously, and two passengers received minor injuries. The aircraft was destroyed.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the flightcrew to recognize and react in a timely manner to the gross deviation from acceptable approach parameters, resulting in a continuation of the descent well below decision height during a precision approach without visual contact with the runway environment.

Although the Board was unable to determine conclusively the reason for the failure to recognize and react to the gross deviation, it is believed that the degraded physiological condition of the captain seriously impaired his performance. Also, the lack of adequate crew coordination practices and procedures contributed to the first officer's failure to detect and react to the situation in a timely manner.

| | | | |
|---|---|---|---|
| 17.Key Words<br>Instrument meteorological conditions; instrument approach; trees; deviation; intentional or unintentional descent; physiological incapacitation; age; hypertension; hypoglycemia; adequate food intake; emotional upset; instrument flying proficiency; fatigue; infarct<br>Identifier: deHavilland DHC-6-300 Accident | | 18.Distribution Statement<br>This document is available to the public through the National Technical Information Service<br>Springfield, Virginia 22151 | |
| 19.Security Classification (of this report)<br>UNCLASSIFIED | 20.Security Classification (of this page)<br>UNCLASSIFIED | 21.No. of Pages<br>27 | 22.Price |

NTSB Form 1765.2 (Rev. 9/74)

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: January 3, 1980

# AIR NEW ENGLAND, INC.
# DeHAVILLAND DHC-6-300, N383EX
# HYANNIS, MASSACHUSETTS
# JUNE 17, 1979

## SYNOPSIS

About 2248 e.d.t., on June 17, 1979, Air New England, Inc., Flight 248 crashed into a heavily wooded area about 1.5 nmi northeast of Barnstable Municipal Airport, Hyannis, Massachusetts. The crash occurred during an instrument landing system approach to runway 24 in instrument meteorological conditions. Of the eight passengers and a crew of two aboard, the captain was killed, the first officer and six passengers were injured seriously, and two passengers received minor injuries. The aircraft was destroyed.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the flightcrew to recognize and react in a timely manner to the gross deviation from acceptable approach parameters, resulting in a continuation of the descent well below decision height during a precision approach without visual contact with the runway environment.

Although the Board was unable to determine conclusively the reason for the failure to recognize and react to the gross deviation, it is believed that the degraded physiological condition of the captain seriously impaired his performance. Also, the lack of adequate crew coordination practices and procedures contributed to the first officer's failure to detect and react to the situation in a timely manner.

## 1. FACTUAL INFORMATION

### 1.1 History of the Flight

On June 17, 1979, an Air New England, Inc., deHavilland DHC-6-300 (N383EX) was scheduled for a series of flights between Barnstable Municipal Airport, Hyannis, Massachusetts, and several New England cities. The original flight schedule included 12 trips (legs) between 4 destinations, beginning at Hyannis at 0905 [1] and terminating at Hyannis at 2030. Weather, equipment, and company personnel problems caused several changes in the original schedule.

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[1] All times herein are eastern daylight, based on the 24-hour clock.

The flightcrew reported for duty about 0845 and flew the 12 legs of the schedule. The first officer stated that he and the captain believed their day was over when they arrived at Hyannis at 1831. However, upon arrival at Hyannis the crew learned that they were to fly two more flights of two legs each. The first officer stated that the captain was annoyed by the instructions from the company. Two other witnesses at the terminal stated that the captain was visibly upset about the additional flights.

The flight from Hyannis to LaGuardia Airport, Flushing, New York, which included an en route stop at New Bedford, Massachusetts, was uneventful except that the captain did not configure his instruments properly for the instrument landing system (ILS) back course approach at New Bedford. The first officer became aware of the problem and advised the captain of his error.

Before loading the aircraft for takeoff from LaGuardia, the flightcrew checked the en route weather for the return flight to Hyannis and learned that a landing at the en route stop at New Bedford might not be possible. When they were advised of the weather situation, the passengers destined for New Bedford decided to remain at LaGuardia. At 2132, N383EX (Flight 248) departed LaGuardia for Hyannis on the last leg of the day. There were eight passengers and two flight crewmembers aboard.

According to the first officer's and a passenger's testimony at the public hearing held during the investigation of the accident, Flight 248 was normal until the approach for landing at Hyannis. At 2234:08, Flight 248 contacted Otis Approach Control [2] and reported level at 5,000 ft. [3] At 2239:05, the flight was given the current Hyannis weather which included an indefinite ceiling of 200 ft, sky obscured; visibility--3/4 mi in fog; wind--210° at 10 kns. It also included a visibility of 1 1/8 nmi in light drizzle on runway 24.

At 2244:36, Flight 248 was 4 nmi north-northeast of the outer marker when Otis Approach Control gave the flight a vector of 210° to intercept the localizer at 1,700 ft for an ILS approach to runway 24 at the Barnstable airport. At 2245:34, Flight 248 was instructed to contact the Barnstable airport tower. About 2247, the flight complied with this request and reported crossing the outer marker. The flight was cleared to land; however, no further transmissions were heard from the aircraft.

The Boston Air Route Traffic Control Center (Boston Center) was able to track Flight 248 to within 2.8 nmi of the intended touchdown point on runway 24. (See Figure 1.) Boston Center's computer printout showed the flight's position at 2246:51 about 0.35 nmi northeast of the ILS outer marker at 1,700 ft. It also showed the flight about 0.15 nmi southwest of the outer marker at 1,500 ft at 2247:03. The last radar position shown for the flight was about 1.1 nmi southwest of the outer marker at 2247:27 at 1,100 ft.

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[2] The Federal Aviation Administration (FAA) facility which controls traffic into and out of Hyannis.

[3] All altitudes herein are mean sea level unless otherwise specified.

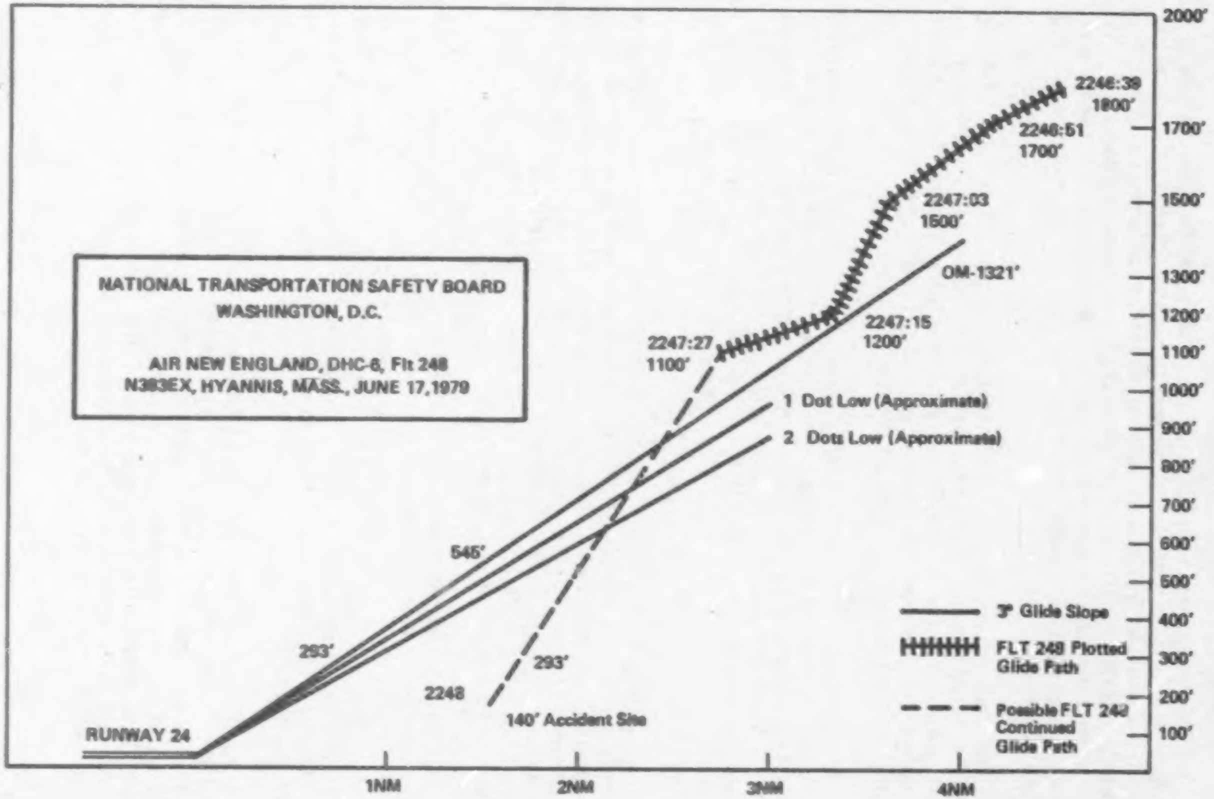

Figure 1.--Probable descent profile of N383EX determined from Boston Center data.

The first officer stated that the captain was flying the aircraft during the approach into Hyannis. He said that he made the following callouts: localizer alive, outer marker, 500 ft above, 200 ft above, 100 ft above, minimums, and 100 ft below. He said that the captain did not acknowledge any of these calls. The first officer said that when he called "minimums," the aircraft was one dot below the ILS glidepath. The first officer said that it appeared that the aircraft was in a continual descent without any excessive sink rates or descent angles from 5,000 ft until impact, with the airspeed near 130 kns for the entire approach. He stated that, as he called "100 ft below," he looked outside the cockpit because he believed that the captain had the approach lights in sight. The first officer said that he did not see the ground before the aircraft crashed about 2248 into a heavily wooded area 1.5 nmi from the approach end of runway 24, on the runway centerline extended.

The accident occurred during the hours of darkness. The coordinates of the accident site were 41° 41' 26" N latitude and 70° 14' 33" W longitude. The elevation of the accident site was about 100 ft.

### 1.2 Injuries to Persons

| Injuries | Crew | Passengers | Others |
|---|---|---|---|
| Fatal | 1 | 0 | 0 |
| Serious | 1 | 6 | 0 |
| Minor/None | 0 | 2 | 0 |

### 1.3 Damage to Aircraft

The aircraft was destroyed.

### 1.4 Other Damage

Numerous trees were destroyed or damaged.

### 1.5 Personnel Information

The flight crewmembers were qualified and certificated for the flight; they had received the training required by current regulations. (See Appendix B.)

Even though the captain's medical records indicated that his distant vision was 20/20, he had a limitation to his first-class medical certificate which required that the "Holder shall wear glasses which correct for near and distant vision while exercising the privileges of his airman certificate." The captain's glasses were found in the cockpit, in their carrying case. The first officer stated that he did not believe the captain was wearing the glasses on this approach or anytime that day while flying.

The investigation revealed that the captain's FAA medical record began with his annual physical examination for his second-class medical certificate performed in 1962. The captain developed hypertension in 1953 as a result of a history of glomerular nephritis. In 1963, a U. S. Marine Corps Reserve aviation physical examination revealed that the captain still had hypertension. He had a sympathectomy, an operation to reduce hypertension, in October 1963. At that time, he was removed from duty involving flying as a pilot in the Marine Corps. His second-class medical certificate was denied by the FAA Regional Flight Surgeon in February 1964 after a physical examination in January 1964 revealed persistent hypertension requiring antihypertension drugs for its control. After a complete cardiovascular evaluation and an apparent return to normal blood pressure levels without the requirement for antihypertensive drugs, the medical certificate was reissued in March 1964, with the requirement for close cardiovascular monitoring.

Until 1968, the captain's annual flight physical examinations resulted in short periods of medical certificate denial and subsequent recertification by the Regional Flight Surgeon after further cardiovascular studies. When the captain's annual physical examination in January 1968 detected blood pressure readings as high as 186/122, his medical certificate was denied by an FAA Aviation Medical Examiner (AME). After extensive evaluations failed to show that the captain met FAA standards for recertification, the denial was upheld by the FAA's Regional Flight Surgeon and referred to the FAA's Federal Air Surgeon in April 1968. His medical records did not show any further cardiovascular evaluations submitted and no medical certificate reissued by the Federal Air Surgeon. However, in August 1970 following 2 1/2 years without apparent medical certification, a physical examination was performed by an AME in Hyannis and a second-class medical certificate was issued after approval, by telephone, by the Chief of the FAA's Aeromedical Certification Branch, Civil Aeromedical Institute, Oklahoma City, Oklahoma.

In August 1971, the captain was issued a first-class medical certificate after a physical examination was performed again by the AME in Hyannis. Since that time, first-class medical certificates had been issued to the captain at 6-month intervals on the basis of physical examinations and cardiovascular evaluations performed by the same AME. On all of these physical examination application forms, the current use of any medication was denied by the captain. Also, the captain's blood pressure was recorded as being within normal limits. However, a cardiologist who reviewed the captain's electrocardiograms after the accident said the tracing could be considered borderline and could be interpreted as abnormal.

In July 1975, the captain's fasting blood sugar was found to be 50 milligram percent (mgm %) and was not subsequently reevaluated. Additionally, the urea nitrogen level was elevated to 26 mgm %, and the uric acid level was elevated to 10.8 mgm %. In August 1978, the fasting blood sugar had elevated to 158 mgm %. An evaluation performed at the request of the FAA reviewing authority in January 1979 revealed normal levels of fasting blood sugar at 97 mgm % and of 2-hour postprandial sugar at 99 mgm %. This abnormal fasting blood sugar determination is one indication of hypoglycemia. However, the captain was never diagnosed as being hypoglycemic.

The captain's latest first-class medical certificate was issued on February 14, 1979. He indicated on the application for this certificate that he currently was not using any medication and had never been denied an airman's medical certificate. The investigation revealed that the captain was on two medications: polythiazide, 1 mgm daily, an antihypertensive medication apparently initiated in 1967 by a doctor in Boston, Massachusetts, and allopurinol, 300 mgm daily, initiated in 1976 by a doctor in Hyannis. The AME in Hyannis denied knowledge of the captain's use of either drug.

The captain's only known food intake on the day of the accident was a Danish pastry and a cup of coffee in the late afternoon between flights.

## 1.6 Aircraft Information

The aircraft was certificated and equipped in accordance with current regulations. There were about 1,000 lbs of Jet A fuel onboard when the aircraft crashed. (See Appendix C.)

The aircraft's weight was within allowable limits both at takeoff from LaGuardia and at the time of the accident. The center of gravity was computed as slightly forward of the forward limit.

The first officer, during his testimony at the public hearing, said that the cockpit lighting in the DHC-6 was adequate; however, it was not bright enough to make the movements of the other pilot easily discernible. He said also that the aircraft's cockpit was extremely noisy and that intra-cockpit communications were difficult without the use of headsets and interphone. These same views have been expressed by other DHC-6 pilots. 4/

## 1.7 Meteorological Information

The weather at Hyannis as observed and recorded before and after the accident by qualified FAA tower personnel at the Barnstable airport was:

> 2237: Indefinite ceiling -- 200 ft, obscured; visibility -- 3/4 mi, fog; temperature -- 67° F; dewpoint -- 66° F; wind -- 210° at 10 kns; altimeter setting -- 29.87 inHg; remarks -- runway 24 visibility 1 1/8 nmi, occasional light drizzle.

A local observation taken at 2249 for the report of the aircraft mishap reported the same weather conditions as at 2237.

Other Air New England aircraft had preceded Flight 248 into the Barnstable airport on the night of the accident. The first officer of one flight which landed at 2130 stated that his aircraft broke out of the clouds at 400 ft. The captain of another flight which landed at 2140 stated that his aircraft broke out of the clouds at approach minimums (293 ft). A piper PA-31 pilot, who flew the ILS approach to runway 24 about 6 min before Flight 248, stated that

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4/ Public Hearing, September 11, 1979, at Cambridge, Massachusetts, concerning the Downeast Airlines, DHC-6 accident at Rockland, Maine, May 30, 1979.

he broke out of the clouds at 300 ft. All of these pilots reported "good" visibility under the clouds.

## 1.8 Aids to Navigation

Not applicable.

## 1.9 Communications

No communications difficulties were reported.

## 1.10 Aerodrome Information

Barnstable Municipal Airport has three hard-surface runways -- runway 11/29, 1,913 ft long; runway 15/33, 4,000 ft long; and runway 06/24, 5,563 ft long. The airport elevation is 52 ft and the elevation of the approach/touchdown zone on runway 24 is 43 ft. The Barnstable tower is in operation until 2300 daily.

Runway 24 is served by an ILS. The weather minimum for this approach is 1 mi visibility at a decision height of 293 ft. Associated with the ILS is a standard ALSF-1 (High) approach lighting system with sequenced flashing lights. The runway is also equipped with high-intensity runway lights. A transmissometer is used by the FAA tower personnel in their determination of current minimum visibility on runway 24.

Three pilots who flew the ILS approach to runway 24 within 1 hr 25 min of Flight 248, including one pilot who flew it 6 min before, stated that the ILS and the approach lighting system were on and functioning correctly. The Barnstable tower, which monitors the ILS, reported no abnormalities or warnings of problems with the system.

The terrain off the approach end of runway 24 rises gently to the accident site and is heavily wooded.

## 1.11 Flight Recorders

The aircraft was not, nor was it required to be, equipped with a cockpit voice recorder or a flight data recorder.

## 1.12 Wreckage and Impact Information

The initial impact was about 30 ft above the base of some trees in a heavily wooded area along the extended centerline of runway 24. The elevation of the base of these trees was 106 ft. The aircraft continued along a heading of 255° striking about 38 trees over a distance of 193 ft before impact with the ground. As the aircraft descended through the trees at descent angles which varied from 4° to 20°, it shed outboard sections from both wings and other small parts.

The aircraft impacted on 10.2° downsloping terrain. It slid about 101 ft before coming to rest upright about 294 ft from the initial impact with the trees and 1.5 nmi from the approach end of runway 24. The wreckage path was about 55 ft wide. There were no signs of fire.

Fairing from the right main landing gear and a latch from the nose baggage compartment door were found near the initial tree contact point. A 13-ft 8-in left-wing outboard section and a 5-ft 8-in right-wing outboard section were located about 120 ft from the initial impact point. All control surfaces and wing flap sections were located in the main wreckage area. There was continuity of control cables and rods from the cockpit to all control surfaces. All exit covers and doors were accounted for.

The nose landing gear was damaged but remained attached to the main structure. The right main landing gear was in position and was slightly damaged. The left main landing gear had separated from the aircraft and was located behind the fuselage.

Both powerplants and their associated propellers were damaged extensively from impact with trees and terrain; however, there was no indication of preimpact failure of these systems or their components.

Hydraulic fluid was present in all reservoirs and accumulators. Open circuit breakers could be related to airframe damage.

Little impact damage was evident along either side of the fuselage from the cockpit/cabin bulkhead aft to the empennage. The cockpit area was partially destroyed by impact with trees. The cockpit was crushed aft about 4 ft on the right side and about 9 ft on the left side. The captain's instrument panel and floor structure back to the cockpit/cabin bulkhead were destroyed. A large tree trunk had passed through the captain's position; the captain's seat was still in the cockpit area, but it had separated from its track attachment.

Most of the flight instruments were destroyed or severely damaged; however, a barometer setting of 29.86 inHg was obtained from one altimeter, all of the radios were set to frequencies associated with the approach phase of flight, and all instrument switches which could be identified were positioned for the approach being conducted at the time of the accident.

The first officer's seat remained in place with minor damage. All but three of the passenger seats remained secure to the cabin floor and wall attach points. The seat in position 1A was separated from its aft floor and wall attachments when trees penetrated the area. Both inboard seat legs were bent forward about 45°. Seat unit 4BC, in which only seat 4C was occupied, was found collapsed on the floor. Both inboard seat leg-to-track attachment fitting buttons had sheared in a forward-inboard direction.

## 1.13 Medical and Pathological Information

The captain's postmortem examination revealed an old, healed myocardial infarct. The infarct was a firm white scar measuring about 3 cm in diameter and involved the inner two-thirds of the myocardial thickness. There was no evidence of a recent injury of the myocardium. The beginning of the left anterior descending coronary artery showed 40 to 70 percent occlusion of the lumen by yellow, eccentric atheromatous plaques. The entire descending aorta showed moderate atherosclerosis with areas of calcification and many areas of intimal ulcerations.

Postmortem toxicologic studies did not reveal the presence of polythiazide, allopurinol, or other drugs.

The captain's injuries included crushing of the chest with rupture of the heart, the aorta, and the bilateral hemothorax. There was also rupture of several other internal organs.

A review of the first officer's medical records revealed no evidence of medical problems that might have affected his performance. The first officer's injuries included a fracture of the left tibia, bilateral fracture of radii, fracture of the sternum, and lacerations of the right lower leg and the left vortex scalp.

Injuries to the passengers included a spinal compression fracture, fractures and lacerations of the extremities, fractured ribs, head injuries, multiple abrasions, contusions, and lacerations.

### 1.14 Fire

There were no indications of preimpact or postimpact fire.

### 1.15 Survival Aspects

### 1.15.1 General

This was a partially survivable accident. With the exception of the cockpit area, the structural integrity of the fuselage was not compromised. All passenger restraints that were used functioned normally. Two passengers were not wearing their seatbelts at the time of the accident and were thrown into the seats in front of them by the deceleration forces. The first officer's restraint system functioned normally; however, the captain's system released sometime during the crash sequence because of impact damage to the seatbelt buckle. The captain was ejected from the cockpit and his body was found about 25 ft forward of the cockpit wreckage. The first officer was conscious but trapped in his seat. He was extricated by two passengers, lowered to the ground, and, at his direction, was administered first aid.

Seatbelt and no smoking signs were on during the entire flight from LaGuardia; however, passengers stated that no announcement was made to fasten their seatbelts. The first officer stated that he made the seatbelt announcement at the same time he advised the passengers that the aircraft would be landing in about 10 min. The passengers did recall the 10 min announcement.

After the aircraft came to rest, the occupants immediately decided to get out of the aircraft because of the strong fuel odor and the threat of fire. All of the passengers recalled the flightcrew's briefing on the emergency procedures before departure from LaGuardia. Furthermore, most of them had read the passenger briefing cards sometime during the flight. Repeated attempts were made by several passengers to open all the emergency exits except the left front emergency window exit. A male passenger said he "couldn't get (the) emergency exits open -- handles came off in (his) hand." The passenger said he removed the passenger briefing card from a seatback to reread it "to see how (the) exits work." He finally was successful in opening the main cabin door wide enough to exit through, but the door would not open completely because of a fallen tree. All of the passengers exited through the partially opened main cabin door. The investigation revealed that the exits were moderately distorted and were blocked from the outside by trees.

While the less seriously injured passengers were seeking an exit route, a medical student onboard the aircraft examined the two seriously injured passengers who were in the left front of the aircraft. The student also checked everyone else before they left the aircraft. The two seriously injured passengers were carried out of the aircraft.

The interior cabin lights remained on while the passengers exited the aircraft. Passengers estimated it took them 15 to 20 min to complete the evacuation. The injured were taken about 50 ft from the aircraft. An uninjured passenger agreed to go for help. She made her way through the woods to a road and flagged down a car. She was driven to the airport and subsequently taken to a hospital.

### 1.15.2 Search and Rescue

The probability of an aircraft accident was first realized by an off-duty Air New England pilot, who, on his way home, saw the airport strobelights go on as he drove by. Expecting an aircraft to land, he pulled into a nearby parking lot. His car was equipped with an aircraft band scanner. He heard the tower response "248 clear to land" and waited for the aircraft. After a reasonable period of time he suspected what had occurred and drove in the direction of a possible crash site along the flightpath where he met a police officer and informed him of what could have occurred. They began searching the immediate area. Shortly thereafter, the officer received a radio transmission informing him of a reported possible aircraft crash near Camp Greenough.

The off-duty pilot and the police officer started toward the entrance of Camp Greenough. En route they encountered the chief of the Yarmouth Fire Department. Using the chief's area map and the pilot's ILS approach plate, they isolated an area to search. A command post was established by the firechief at the entrance to the camp.

State police records indicate that an organized search in the area of Camp Greenough began at 2315. Approximately 49 persons were involved in the search. The downed aircraft was located within 1 hr after the search began and 1 hr 28 min after the crash. Gaining access to the accident site was difficult. Vehicle access was limited to a small dirt service road which was widened using fire department brush breakers.

Some onscene first aid was administered to the injured by the first rescuers who arrived. Once paramedics and the emergency medical technicians arrived, additional medical procedures were performed. The majority of the ambulances used by the responding local fire departments were capable of communicating directly with the Cape Cod Hospital Emergency Room and transmitted the victims' vital signs, EKG traces, etc.

The Yarmouth Fire Department had 48 of its 65-man firefighting force involved in the emergency at one point. Local fire departments from Hyannis, Dennis, Harwich, Barnstable, and West Barnstable provided 15 additional men and one ambulance each.

The Cape Cod Hospital in Hyannis was advised by the State Police at 0015 that it would be receiving about 10 casualties. The hopital's newly developed disaster plan was not activated because most of the personnel from two shifts were in the hospital at the time and were retained. All of the casualties of this accident were taken to the Cape Cod Hospital. The first casualty was admitted at 0140. The last casualty was admitted at 0428.

### 1.16 Tests and Research

None

### 1.17 Other Information

### 1.17.1 Air New England Callouts During Approach

The company procedure for standard callouts by the nonflying pilot during an instrument approach are:

"(1) 500 ft above minimum descent altitude (MDA) or decision height (DH);

(2) 200 ft above MDA or DH;

(3) 100 ft above MDA or DH;

(4) MDA or DH;

(5) While on final - anytime a deviation of more than 1 dot - should be called out and acknowledged;

(6) Sink rate should be monitored closely -- excessive sink rate beyond the final approach fix (FAF) will be called and acknowledged;

(7) Whenever an airspeed excursion of minus 0 or plus 10 kns from planned final approach speed is observed, it will be called out and acknowledged.

(8) At Missed Approach Point (MAP)--runway in sight or no contact."

### 1.17.2 Air New England Crew Procedures

The normal company crew coordination procedures for all IFR approaches are:

"(1) At not less than 100 ft above MDA or DH -- Pilot not flying directs primary attention outside;

(2) At DH or MAP -- if the pilot not flying calls out "No contact" the pilot flying will immediately call out "Go Around";

(3) Full scale deflection of either glide slope or localizer needle inside the FAF will require the immediate execution of the missed approach procedure."

### 1.18 New Investigation Techniques

None

## 2. ANALYSIS

### 2.1 The Accident

The flightcrew was properly certificated and qualified in accordance with company and FAA requirements.

The aircraft was certificated and maintained according to applicable regulations. There was no evidence of preimpact failure, malfunction, or abnormality of the airframe, systems, or powerplants.

Because of the circumstances of the accident and because the aircraft's ILS equipment was too damaged to be tested adequately, the possibility of an aircraft ILS system malfunction was considered. However, the first officer's testimony that his ILS instruments appeared to be functioning normally, that no off-flags were visible on any of his instruments, that a positive identification of the Hyannis ILS was received at the outer marker, and that the aircraft's ILS equipment had operated normally during the previous approach at LaGuardia seemed to eliminate or at least lessen considerably the possibility of an aircraft ILS system malfunction.

The possibility that the Hyannis ILS malfunctioned is remote because of two factors. First, the ILS monitoring system in the Hyannis tower showed no abnormalities or warnings. Second, a pilot who had landed at Hyannis utilizing the ILS approach about 6 min before Flight 248 stated that the ILS and the associated approach lights functioned normally. Furthermore, if either the aircraft's ILS instruments or the airport's ILS equipment had malfunctioned during the approach, the captain should have leveled immediately and conducted a missed approach if the airport environment was not visible. Therefore, the Safety Board concludes that the accident was not related to an equipment malfunction.

Flight 248 struck trees about 1.5 nmi northeast of the approach end of runway 24 at an altitude of about 140 ft. If the aircraft had been on the 3° ILS glideslope into the Barnstable airport, it would have been at an altitude of about 545 ft at that distance from the runway. Therefore, the aircraft was 405 ft below the normal glide slope altitude and 153 ft below the decision height of 293 ft when it struck the trees.

Flight 248's approach profile (see Figure 1) was derived from a computer printout from the Boston Center. The computer printout is accurate to within 200 ft in altitude, 1/8 mi in range, and 0.26° in azimuth. Three significant readouts obtained from the computer printout placed Flight 248 at 1,560 ft at the outer marker, at 1,500 ft 0.15 nmi inside (southwest) of the outer marker at 2247:03, and at 1,100 ft 1.1 nmi inside of the outer marker at 2247:27. The distance between the last computer-plotted position of Flight 248 and the accident location is 1.29 nmi.

The first officer testified that the aircraft's indicated airspeed was about 130 kns during the approach. Because of a headwind of about 10 kns, the aircraft's ground speed was close to 120 kns. This ground speed is consistent with the information derived from the computer printout, which had Flight 248 traversing the 5.74 nmi before its last plotted position in 2 min 48 sec, which represents a ground speed of 123 kns. From the aircraft's last plotted position at 1,100 ft to the crash site, Flight 248 covered 1.29 nmi and descended 960 ft. Assuming that Flight 248 began its descent from its last plotted position at 1,100 ft at 2247:27, the aircraft would have had to descend at 1,488 ft/min with a descent angle of 6.976° in order to impact the ground 1.5 nmi from the end of runway 24.

The first officer's recollection of Flight 248's flight profile differs from the one constructed from the computer printout. The first officer testified that Flight 248 crossed the outer marker at the proper altitude (1,321 ft). Since the aircraft crashed 2.3 nmi inside the outer marker at 140 ft, the aircraft's descent rate would have been 925 ft/min with a descent angle of 4.3° if the flight crossed the outer marker at 1,321 ft. For a ground speed of 120 kns, the aircraft's normal rate of descent for a 3° glide slope is 646 ft/min.

The first officer also testified that when he called minimums, the aircraft was one dot below the glide slope. Assuming a 6.976° descent angle, Flight 248 would have descended through the 293-ft decision height about 1.69 nmi from the runway. At 1.69 nmi from the runway, a one dot-low indication represents a position about 50 ft below the 3° glide slope. However, Flight 248 was actually 400 ft below the glide slope when the aircraft descended through minimums, and the glide slope indicator should have indicated full-scale deflection.

The profile as derived from the computer printout is believed to be the most accurate presentation of Flight 248's actual flightpath for two reasons. First, the computer printouts have been historically accurate and comparison to past accident aircrafts' flight data recorders has substantiated their accuracy. Second, the first officer's recollection of the aircraft's flight profile is contrary to a number of known facts. For example, since the aircraft crashed 1.5 nmi from the runway it would have been impossible for Flight 248 to be only one dot below the ILS glide slope when it descended through minimums. Also, the first officer stated that he did not recall any excessive sink rates or descent angles. Even if Flight 248 had passed over the outer marker at the normal altitude of 1,321 ft, it would have required a 925 ft/min descent rate and a 4.3° glide slope to reach the accident location.

The Safety Board believes that Flight 248 approached the outer marker 300 ft high, crossed the outer marker 220 ft high, remained above the glide slope until about 1.4 nmi inside the outer marker, began a steeper than normal descent about 1.25 nmi inside the outer marker, and maintained this descent until ground impact. The Safety Board concludes that Flight 248's altitude and descent angle were controlled in an imprecise and careless manner.

## 2.2 The Captain's Role

While Flight 248's flight profile has been established, the question of why the aircraft was 400 ft low 1.5 nmi from the runway must be explored. The captain, who was flying the aircraft, could have intentionally descended to decision height and below in an attempt to visually acquire a familiar landmark, the ground, or the approach lights. Testimony at the public hearing revealed that this captain had used a similar "duck under" procedure on other flights. On one occasion while flying an ILS approach into Hyannis in similar weather conditions, he descended through the glide slope. However, on that flight the pilot in the right seat was a qualified captain who took control of the aircraft at 600 ft and leveled out at 200 ft. The majority of Air New England pilots who were interviewed stated that the captain of Flight 248 disregarded checklists and crew coordination when they had flown with him.

Although past instrument approaches by this captain may lend credence to the possibility that he intentionally descended to the decision height and below, certain other factors tend to diminish the possibility of an intentional descent. Very little could have been gained by descending below a precision glidepath in such poor ceiling and visibility conditions. The steep descent angle which was initiated late in the approach and which was maintained through the decision height is not conducive to looking for the ground or lights or for leveling off. The higher than normal airspeed that was maintained could have placed an added burden on a pilot who was intentionally descending below a decision height. It seems improbable that a pilot would fly the aircraft above the glide slope early in the approach and then descend steeper and faster than normal while intentionally descending through the decision height.

It is possible that the captain's intention was to descend to and level at decision height and that a combination of other human performance-related factors had degraded his skills enough so that he was unable to arrest the descent or stabilize at the decision height. One of the factors that may have contributed to an unintentional descent below the decision height was deteriorated flying proficiency. Although the captain had accumulated over 20,000 flight-hours and over 3,500 hours of instrument flight time, his recent flying time had been limited to 12 hours in the last 90 days before the day of the accident. According to statements from pilots who had flown recently with the captain, most of his recent flying was in visual meteorological conditions. Also, the captain approached the outer marker initially at 1,800 ft when he could have been at 1,400 ft until intercepting the glideslope outside the outer marker. It is possible that the captain's proficiency, particularly in instrument meteorological conditions, was degraded by the lack of recent experience.

There were also aeromedical factors which could have contributed to a continued unintentional descent. Because of the onset of hypertension in 1953 from a history of glomerular nephritis leading up to a sympathectomy in 1963, he was permanently removed from duty involving flying as a pilot in the U.S. Marine Corps. He was able to continue his career in commericial aviation with the requirement for close cardiovascular monitoring by the FAA even though the results of repeated evaluations were equivocal medically. At the time of the accident, the exercise of his Airline Transport Pilot Certificate was limited to operation under 14 CFR 135 because of the existing "over 60 rule" contained in 14 CFR 121.

A review of available medical records for the captain revealed findings of significance relating to preexisting disease. In addition to nonspecific electrocardiogram changes, abnormal blood chemistry determinations were apparent. Both blood urea nitrogen levels and uric acid levels were elevated. In addition to these, and of even more significance, fasting blood sugar was elevated on one occasion and was lower than normal on another, indicating the probable existence of an error in glucose metabolism and a possible predisposition to hypoglycemia.

While the existence of hypertensive cardiovascular disease was well documented in medical evaluations since 1963, the fact that the captain had suffered a subclinical myocardial infarction sometime before the accident was not detected by the required cardiovascular evaluations for continued FAA certification. The presence of the well healed myocardial infarct was noted on the postmortem examination after the accident. Of further significance, and also not detected by the required stress testing, were the atherosclerotic changes in the left anterior descending coronary artery resulting in from 40 to 70 percent occlusion.

The human factors investigation revealed that the captain was currently taking polythiazide and allopurinol. This information was not reported by the captain on his FAA physical examination form, and the AME denied knowledge of the captain's use of medication. However, the captain's past military medical records did indicate the use of these drugs. Polythiazide is a diuretic commonly used in the treatment of hypertension, and allopurinol is prescribed for the treatment of gout. While both drugs are among those which can be "waivered" by the FAA for pilot certification, such a waiver had not been considered in the captain's case because the AME and the FAA were not aware of their use. Postmortem toxicologic studies did not reveal the presence of these or other drugs, but discussion with the toxicologist at the FAA's Civil Aeromedical Institute indicated that these particular drugs were difficult to detect in therapeutic levels.

Because he was in management at Air New England, the captain flew only occasionally as a replacement pilot. Early in the morning, on the day of the accident, he had been notified that he was needed to replace a line pilot and he reported for duty about 0845 for a scheduled 12.5-hr duty day. At 1830 at Hyannis, after several changes in the flying schedule during the day, he had anticipated the end of his duty day and was visibly upset when informed that it was necessary to extend his day for about 5 hrs to fly additional scheduled flights.

The accident occurred about 2248 during the 15th approach for landing at the end of a 14-hr duty day. A 14-hr duty day including 9 hrs 16 min actual flight time and 15 approaches in an aircraft well known for its dark, noisy cockpit environment would almost certainly have produced some degree of pilot fatigue even in the hardiest individual and particularly in an individual who was almost 61 years old and had chronic hypertensive cardiovascular disease. The probability also exists that the captain was predisposed to hypoglycemia because of an apparent error in glucose metabolism — it is significant that his only known food intake during the 14-hr duty day was a Danish pastry and a cup of coffee during the late afternoon while on the ground between flights. Symptoms of hypoglycemia such as subtle mental confusion, slowing of cognitive processes, and diminution of psychomotor ability cannot be distinguished from symptoms of fatigue and, even when mild, would certainly contribute to the effects of fatigue. These physiological factors, which are known contributors to the degradation of human performance, were further compounded by the captain's emotional upset over the extension of his duty day.

The Safety Board believes that the multiple stresses which contributed to the captain's physiologic fatigue, in concert with his personal flying habits (disregard for procedures and lack of communication with his first officer) and his age, contributed greatly to a marked human performance degradation.

## 2.3 The First Officer's Role

The DHC-6 cockpit is dark and it is difficult for one pilot to see and assess the actions of the other pilot. Further, neither pilot can easily see the other pilot's flight instruments. The cockpit is also noisy, making verbal communication difficult except by use of headsets and interphone. The captain was a company vice president with over 20,000 flighthours who was known to rarely acknowledge checklist items or other callouts from any first officer. The first officer, although previously qualified in the DHC-6, had only been with the company for 2 months. For the first year, pilots are on probation, are not represented by the pilot's union, and may be terminated with or without cause.

It was within this environment that the first officer's role in this accident must be evaluated. The first officer testified that he made all of the required callouts except the "no contact" call and that the captain did not acknowledge any of his calls. Because the captain rarely acknowledged calls, even calls such as one dot low, this lack of response probably would not have alerted the first officer to any physiologic incapacitation of the captain. However, the first officer should have been concerned by the aircraft's steep glidepath, excessive descent rate, and high airspeed. These three factors limited the amount of time available to the first officer to react once Flight 248 descended through the decision height.

The poor altitude and pitch control exhibited by the captain and the steep descent rate that the aircraft achieved should have alerted the first officer to the existence of an abnormal situation. However, a flight simulator study of subtle incapacitation conducted by United Air Lines demonstrated that recognition of the phenomenon by the other crewmember is a difficult task. 5/ In the United simulator study, when the captain feigned subtle incapacitation while flying the aircraft during an approach, 25 percent of the aircraft hit the "ground." The study also showed a significant reluctance of the first officer to take control of the aircraft. It required between 30 sec and 4 min for the other crewmember to recognize the captain was incapacitated and to correct the situation. The first officer of Flight 248 had 1 min 9 sec from the outer marker to impact. It is quite possible that the first officer also was suffering from fatigue which dulled his senses and reactions.

If Flight 248 was descending at 1,488 ft/min, it would have descended from the decision height to impact in about 6 sec and from 100 ft below decision height to impact in 2 sec. The short time available from decision height to impact coupled with a usual nonresponsiveness of the captain to callouts made it extremely difficult, if not impossible, for the first officer to detect a deteriorating situation and react once he called decision height and verified that no approach lights were visible. The Safety Board believes that the limited time from descent through the decision height to impact combined with the previously cited factors made the possibility that the first officer could have successfully assumed control of the aircraft after decision height extremely remote. However, the Safety Board also believes that the first officer should provide the maximum feasible redundancy in the cockpit during a landing approach. The gross deviation from glidepath, descent rate, and airspeed should have alerted him to the possible need for further action on his part during the latter stages of the approach.

## 2.4 Survivability Aspects

Assuming that the aircraft's groundspeed was 120 kns and the rate of descent was 1,488 ft/min, the aircraft's initial impact with the trees was at a velocity of 204.37 ft/sec at an angle of 6.97°. Since the aircraft descended to the ground through trees, the rate of the onset of g-forces, both vertical and horizontal, was assumed to increase linearly as the aircraft impacted the lower,

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5/ "Study of Simulated Airline Pilot Incapacitation: Phase II, Subtle or Partial Loss of Function," Aerospace Medicine, Volume 42, Number 9, September 1971. This flight simulator study culminated in a training film.

larger, more rigid tree trunks. Vertical and horizontal stopping distances, including airframe crushing and earth crushing plus the distance traversed were 30 ft and 303 ft, respectively. Thus, the resultant g-loads along the horizontal and vertical axis of the aircraft were determined to be 5.69 g's and 0.14 g, respectively. These peak g-forces are a best estimate of the probable magnitude of the crash forces experienced in this accident by those individuals not located in the area of destruction. These estimated g-loads seem to be consistent with what was seen within the aircraft because the horizontal decelerative forces were below the design load of 9 g's where failure would normally be expected. In addition, the vertical g-loads were described by passengers as merely resembling moderate turbulence.

Crash survivability in general refers to structural crashworthiness, tie-down chain strength, occupant acceleration environment, interior environment hazards, and postcrash hazards. In this accident, the first four survivability factors were significant. However, postcrash hazards did not develop mainly because there was no postcrash fire.

Considering the aircraft's crashworthiness, the structural integrity of the aircraft's fuselage was compromised primarily in the cockpit region. The cabin remained virtually intact except for some floor disruption and tree penetration localized at the left front. The failure to maintain a living space for all occupants during the crash sequence was exhibited by the complete destruction, by multiple tree impacts, of the left side of the cockpit and a small portion of the left front cabin. This encroachment into the occupant environment produced the more serious and fatal injuries.

The tie-down chain for passenger seats was actually severed at only one seat location due to decelerative forces. The seat failure was influenced by local fuselage deformation. Seat unit 4BC collapsed because the sidewall buckled and a missing locking pin on the side wall attach fitting permitted the side wall attachment button to pull out of the track. Once the side wall attachment was compromised, and because the inboard seat legs were hinged at the seat pan, the seat collapsed. Consequently, under the decelerative forces, the seat leg attach buttons were sheared off. However, the collapse of the seat did not produce any significant injuries. Nevertheless, the injury potential of seat failures of this nature in this and other survivable accidents is considerable.

In addition, the failure of the pilot's restraint system at the buckle did not influence his chance for survival. Although he was ejected from the aircraft as a result of this failure, his fatal injuries were caused by trees impacting the left cockpit and by the collapsing cockpit structure as the aircraft descended through the trees. It was during this portion of the crash sequence that the restraint system buckle sustained a direct impact, most likely from the collapsing instrument panel or other nearby structure. This blow broke two spacers inside the buckle, thus permitting the retraction of all of the springloaded dogs which held the lapbelt and shoulder harness inserts. This action released the entire restraint system including the fixed left lapbelt, permitting the captain to be thrown clear of the wreckage when the aircraft came to a stop.

The structural deformation and resultant dissipation of energy which occurred when the aircraft collided with the trees served to reduce the magnitude and to extend the duration of the decelerative forces imposed on the occupants seated aft of the area of the destroyed section of the cabin. The reduced forces resulted in much less severe injuries in most cases, as compared to those injuries sustained by occupants exposed to the blunt impact forces caused by the penetrating trees. Most of the serious injuries were due to secondary impacts with bulkheads, seatbacks, and ashtrays. The severity of the injuries sustained by the two passengers who were not wearing their lapbelts could have been markedly reduced had they been restrained and properly positioned in their seats. The occupant acceleration environment for most of the passengers was within survivable limits, and the interior environment hazards produced injuries to both restrained and unrestrained passengers.

This accident must be considered partially survivable since several of the survivability factors were violated and since fatalities occurred. A definition of a survivable accident is one in which the forces transmitted to the occupant do not exceed the limits of human tolerance to abrupt acceleration, either positive or negative and in which the structure in the occupant's immediate environment remains substantially intact to the extent that an occupiable volume is provided for the occupants throughout the crash sequence. In this accident, only a portion of the aircraft fuselage's structural integrity was breached and only some of the occupants were exposed to decelerative forces beyond the limits of human tolerance.

### 2.5 Flight Recorders

The investigation of this accident was made more difficult by the lack of definitive information concerning the aircraft's actual flightpath and the flightcrew's actions and procedural conduct. Information from a flight data recorder and a cockpit voice recorder would have provided invaluable information and would have contributed significantly to the total investigative effort. The Safety Board believes, as it has stated in the past, that these recorders are virtually a prerequisite to improvements in safety in commuter/airtaxi operations involving complex multiengine aircraft.

## 3. CONCLUSIONS

### 3.1 Findings

1. The flightcrew was properly certificated and qualified.
2. The aircraft was properly certificated and maintained according to approved procedures.
3. The aircraft was 220 ft high at the outer marker.
4. The distance from the aircraft's last plotted position to impact was 1.29 nmi.

5. From the aircraft's last plotted position to impact, the aircraft descended at 120 kns ground speed with a descent rate of 1,488 ft/min and a descent angle of 6.976°.

6. The aircraft descended from the decision height to impact in 6 sec.

7. The captain was almost 61 years old, a company vice president, and a part-time line pilot for 14 CFR 135 operations only.

8. The first officer had been with the company only 2 months.

9. The captain may have lacked proficiency in the DHC-6 as he had flown only 12 hours in the 90 days preceding the day of the accident.

10. The captain's lack of recent flying time in instrument meteorological conditions may have resulted in deteriorated instrument flying proficiency.

11. The captain had developed hypertension while in military service. Both his military and FAA medical records reflect the existence of hypertensive cardiovascular disease.

12. The captain's FAA medical records indicate nonspecific electrocardiogram changes, abnormal blood chemistry, and occasional elevated fasting blood sugar.

13. The captain's autopsy findings revealed a well healed myocardial infarct and a 40 to 70 percent occluded left anterior coronary artery.

14. The captain wes taking polythiazide, a hypertensive medication, and allopurinal, a gout medication.

15. The captain listed no medications on his most recent FAA medical application form; however, his military medical records indicate the use of these drugs. Both drugs can be waivered by FAA AME's if the use of the drugs is known.

16. The captain's only known food intake occurred in the late afternoon between flights.

17. The Hyannis weather was near approach minimums which forced the flightcrew to fly the ILS and significantly increased the crew's workload.

18. The crew had worked to a 14-hr duty day involving 9 hrs 15 min of flight time.

19. The captain was outwardly upset when ordered to undertake additional flights at the conclusion of his anticipated workday.

20. The probability of the first officer recognizing and reacting to any possible physiologic incapacitation in the captain was remote.

21. Two passengers were not wearing their lapbelts.

22. Longitudinal crash loads were estimated to be 5.7 g's, which is within the limits of human tolerance.

23. Vertical crash loads were estimated to be 0.14 g which also is within the limits of human tolerance.

24. The structural integrity of the aircraft's occupiable volume was partially compromised.

25. There was no fire.

26. The fatal and more serious blunt trauma injuries of the occupants in the front of the aircraft were a direct result of the loss of structural integrity in this area because of impact with trees.

27. The less severe injuries were caused by secondary impacts with surrounding structure such as seatbacks and bulkheads.

28. The accident was partially survivable since the major part of the occupiable volume was virtually intact and the decelerative forces were within the limits of human tolerance.

### 3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the flightcrew to recognize and react in a timely manner to the gross deviation from acceptable approach parameters, resulting in a continuation of the descent well below decision height during a precision approach without visual contact with the runway environment.

Although the Board was unable to determine conclusively the reason for the failure to recognize and react to the gross deviation, it is believed that the degraded physiological condition of the captain seriously impaired his performance. Also, the lack of adequate crew coordination practices and procedures contributed to the first officer's failure to detect and react to the situation in a timely manner.

## 4. SAFETY RECOMMENDATIONS

As a result of this accident, and other commuter air carrier accidents, the Safety Board issued the following recommendation to the Federal Aviation Administration on October 17, 1979:

Expedite rulemaking which would make the flight time and duty time limitations, and rest requirements for commuter air carriers the same as those specified for domestic air carrier crewmembers under 14 CFR 121. (Class II, Priority Action) (A-79-81)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G.H. PATRICK BURSLEY
Member

January 3, 1980

# 5. APPENDIXES

## APPENDIX A

## INVESTIGATION AND HEARING

### Investigation

The Safety Board was notified of the accident about 0310 e.d.t., on June 18, 1979. The investigative team went immediately to the scene. Working groups were established for operations, air traffic control, systems/structures, powerplants, maintenance records, human factors, and weather.

Participants in the onscene investigation included representatives of the FAA, Air New England, Inc., deHavilland Aircraft of Canada, Ltd., the Air Line Pilots Association (ALPA), Pratt & Whitney Division of United Technologies Corporation, and Hartzell Propeller Company.

### 2. Public Hearing

A 2-day public hearing was held in Cambridge, Massachusetts, beginning September 13, 1979. Parties present at the hearing were Air New England, Inc., FAA, ALPA, and the Transport Workers Union.

# APPENDIX B

## PERSONNEL INFORMATION

### Captain George Edward Parmenter

Captain George Edward Parmenter, 60, had been with Air New England since its formation and was a vice president of the company. He held Airline Transport Pilot Certificate No. 102193 for airplane multiengine land and single-engine land and sea. He was a certified flight instructor--airplane and instruments. He had a first-class medical certificate dated February 14, 1979, with the limitation that "Holder shall wear glasses which correct for near and distant vision while exercising the privileges of his airman certificate."

Captain Parmenter passed his last proficiency check in the DHC-6 on June 12, 1979. He had accumulated about 25,101 total flight-hours, 951 hours of which were in DHC-6 aircraft. His total instrument time was 3,542 flight-hours. His flying time during the last 90 days and 30 days were 21 hrs 16 min and 12 hrs 16 min, respectively, including the time accumulated on the day of the accident. In the last 24 hours he had flown 9 hrs 16 min. His duty time for the last 24 hrs was 14 hrs and his rest period in the 24 hrs before reporting for duty on the day of the accident was over 20 hrs.

### First Officer Richard Daniel Roberti

First Officer Richard Daniel Roberti, 32, was hired by Air New England, Inc., in April 1979. He holds Airline Transport Pilot Certificate No. 2016426 for airplane single- and multiengine land. He has a first-class medical certificate dated March 12, 1979, with the limitation that "Holder shall wear corrective lenses at all times while exercising the privileges of this airman's certificate."

First Officer Roberti had passed his DHC-6 flight check and was qualified as a first officer on May 2, 1979. He had accumulated about 4,362 flight-hours, 102 hours of which were in DHC-6 aircraft. His total instrument time was 429 hrs; total night time was 502 hrs. His flying time during the last 30 days was 64 hrs 16 min, including the time accumulated on the day of the accident. In the last 24 hours he had flown 9 hrs 16 min. His duty time for the past 24 hours was 14 hrs 30 min and his rest period in the 24 hours before reporting for duty on the day of the accident was over 20 hrs.

## APPENDIX C

## AIRCRAFT INFORMATION

DeHavilland DHC-6-300, serial No. 245, was owned and operated by Air New England, Inc. It was certificated and maintained according to procedures approved by the FAA. At the time of the accident, the aircraft had accumulated 17,058.2 flight-hours; 82.4 flight-hours had been flown since the last major inspection.

The aircraft was equipped with two Pratt & Whitney of Canada, Ltd., PT6A-27 turboprop engines and two Hartzell Propeller, Inc., Model HC-B3TN-3DY, three-bladed propellers.

### Engine Data

| Installed position: | Left | Right |
|---|---|---|
| Serial numbers: | PC-E40160 | PC-E40137 |
| Total times (hrs): | 16,415.7 | 16,631.8 |
| Total cycles: | 30,509 | 31,234 |
| Time since last overhaul (hrs): | 6,592.3 | 6,938.4 |
| Date of installation: | 01-02-78 | 01-03-79 |
| Date of manufacture: | March 1969 | February 1969 |

### Propeller Data

| Installed position: | Left | Right |
|---|---|---|
| Hub serial number: | BU4193 | BU2594 |
| Total time (hrs): | 8,379.1 | Unknown |
| Time since last overhauls (hrs): | 1,834.9 | 1,424.6 |
| Date of installation: | 08-10-78 | 03-05-79 |
| Date of manufacture: | 07-30-73 | 04-05-69 |

Attachment #11

# EVALUATION OF AIRCRAFT ACCIDENT REPORTS

on

United Airlines, Inc.
Douglas DC-8-54 N8047U
near Kaysville, Utah
December 18th 1977

## REPORTS REVIEWED

1. National Transportation Safety Board Report
   NTSB-AAR-78-8

2. Model of probable fatigue factors involved in United Airlines Flight No. 2860 Accident, December 18, 1977, Salt Lake City, by Captain William J. Price, United Airlines Task Force on Pilot Fatigue
   Airline Pilots Association
   Burlingame, California - January 6, 1978

by

Martin C. Moore-Ede, M.D., Ph. D.

and

Charles A. Fuller, Ph. D.

Department of Physiology
Harvard Medical School
Boston, Mass. 02115

October 26th 1978

## 1. INTRODUCTION

At about 01:38 hours, Mountain Standard Time, on December 18, 1977, a United Airlines Inc. DC-8F-54 cargo aircraft, operating as Flight 2860, crashed into a mountain in the Wasatch Range near Kaysville, Utah. The three flight crew members, the only persons aboard the aircraft, were killed, and the aircraft was destroyed.

The causes of this aircraft accident were investigated according to routine procedure by the National Transportation Safety Board. The conclusions of the investigation team were documented in National Transportation Safety Board Report NTSB-AAR-78-8 issued on July 27, 1978. This report documents multiple small procedural errors by the flight crew and the approach-local controller which cumulatively appeared to cause the accident. The NTSB concluded that the probable cause of the accident was the approach-controller's issuance and the flight crew's acceptance of an incomplete and ambiguous holding clearance in combination with the flight crew's failure to adhere to prescribed impairment-of-communications procedures and prescribed holding procedures.

Captain William J. Price of the United Airlines Task Force on Pilot Fatigue issued on the 6th of January 1978 a "Model of Probable Fatigue Factors Involved in United Airlines Flight No. 2860 Accident". In this Model Captain Price argues that the work schedules imposed on the air crew and the air traffic controller contributed to the accident by causing problems of sleep disruption and circadian desynchronosis. The conclusions of Captain Price's Model were not recognized in the final report of the National Transportation Safety Board.

Our evaluation of circadian human performance as a contributory cause of this aircraft accident was undertaken at the request of Captain William Price. Two questions will be addressed here:

a. Could changes in work shift schedule and time of day available for sleep influence a pilot's performance in such a way to be a possible contributing factor in an aircraft accident?

b. Is there evidence from the data presented in the reports of the NTSB and Captain Price that would indicate such circadian factors played a role in the crash of United Airlines Flight No. 2860?

## 2. IMPLICATIONS OF CIRCADIAN PERFORMANCE RHYTHMS FOR AIR OPERATIONS

Many hundreds of physiological, biochemical and psychological functions have been shown to have prominent circadian rhythms in man which reach a maximum value at one point in each 24-hour day, and a minimum value at another time (Conroy and Mills, 1970; Bunning, 1973). Critical factors of the type which might influence aircraft operations are no exception. Lowest levels of performance are seen during the nighttime hours in such variables as the delay of switchboard operators in answering calls (Browne, 1949), the frequency of errors in reading meters (Bjerner et al., 1955) and the tendency to fall asleep while driving on long distance operations (Prokop and Prokop, 1955). In each of these studies, the variability in performance around the 24-hour mean was between 50 and 100 percent, thus representing a considerable time of day dependence.

The direct relevance to aircraft pilots has been demonstrated in studies of aircraft simulator performance throughout day and night. Again it was found that there were significant circadian variations in the performance of the subject (Klein et al., 1972). In this case, there was an approximately 25% variation in performance around the mean performance throughout the 24-hour day. An additive factor of importance (Coates et al., 1974) is the deterioration with performance in a sustained operation (e.g., a long aircraft flight) which markedly depends on the phase of the circadian cycle it coincides with. (See Klein et al., 1977 for discussion.)

Circadian rhythms are generated by endogenous oscillators or clocks within man which are normally synchronized to the 24-hour day-night cycle. The circadian performance rhythms are but one of the many hundreds of variables which are controlled by these internal clocks. The internal timekeeping system and, therefore, the performance rhythms only slowly readjust when an individual is rapidly transported from one time zone to another, or changes from the day to night work shift. The adjustment of the circadian timing system to the new schedule may take a week or more. The studies of Klein and his colleagues (see Klein et al., 1977) have demonstrated that this is also true for circadian performance rhythms in aircraft simulators.

Such sudden changes in the work schedule as would be met by an air crew flying from one time zone to another, or an air crew starting to fly at night instead of day, may have serious impact upon performance. For example, the time of minimum performance, which usually occurs in the early hours of the morning when the subject is in the middle of his rest period, may suddenly be the time when the pilot is required to undertake a difficult landing. More important dangers may occur in situations where there is not a high level of awareness in the aircraft cabin of the problems with which the air crew is faced. Thus, while a highly motivated and aware individual may be able to overcome any mean circadian performance decrement when he is fully alert to the danger, when he is not aware that a dangerous situation has occurred, he may make small, but eventually cumulatively fatal, mistakes due to lack of alertness.

These conclusions are borne out by studies which compare shift workers on rapidly rotating shift schedules to those on shifts which they have become adjusted to over a period of weeks or months. Such studies have shown that rotating shift workers have more accidents than fixed shift workers. About 20% more rotaters than fixed shift workers reported having at least one accident during a six month study of workers in hospital and industrial environments (Tasto et al., 1978). In addition, rotating shift workers who do not have time to adjust to the shift work schedules they are on, show a significantly higher incidence of fatigue, inadequate sleep patterns, nervousness and less satisfactory work performance.

An important additional problem for air crew and flight controllers who are on rotating shift schedules is the sleep loss that these individuals may suffer. When provided with an opportunity to sleep at various times of day, with the same prior-awake time, it has been shown by Weitzman et al. (1970, 1974) that the quality and quantity of sleep is markedly circadian phase-dependent. Hence the provision of a daytime interval in which to sleep for someone who is starting a night shift does not ensure that adequate sleep will occur during the interval that is available for rest.

Loss of sleep per se in an individual who is adjusting to a change in shift may have important effects on performance per se. Wilkinson (1961) has shown performance decrements after the loss of sleep, especially in situations where there was little feedback on how well the subject was performing during the test. This situation, Wilkinson points out, is highly relevant to aviator performance where there may not always be adequate feedback about all parameters of their piloting performance.

These problems may be compounded in situations where there are frequent shifts in work schedule as are suffered by pilots on prolonged tours of duty on around-the-world flights. A study by Nicholson (1973) has shown the considerable loss of sleep that occurs in pilots undertaking such schedules. In less than half the rest periods was a full sleep interval achieved.

## 3. EVALUATION OF FLIGHT NO. 2860 ACCIDENT AS DOCUMENTED BY NTSB REPORT AND PRICE MODEL

An examination of the evidence provided in the NTSB Report illustrates that there were "numerous acts of omission and commission, the slight alteration of which probably could have prevented the accident" (Page 24).

Our evaluation of the NTSB Report focused on whether there was any evidence for circadian performance decrement. This evaluation was greatly hampered by the lack of useful information in the NTSB Report. In order to evaluate circadian factors, complete documentation is needed over the previous ten days of the exact times of sleep and wake, and exact times of duty for each of the parties involved. We have attempted in Figures 1 through 3 to plot these times from the evidence available in the Report. It is apparent that there are major amounts of missing information which would make it impossible to assess whether the individuals involved were operating at a time near their circadian subjective minimum performance, and whether shifting work schedules were a factor in this accident.

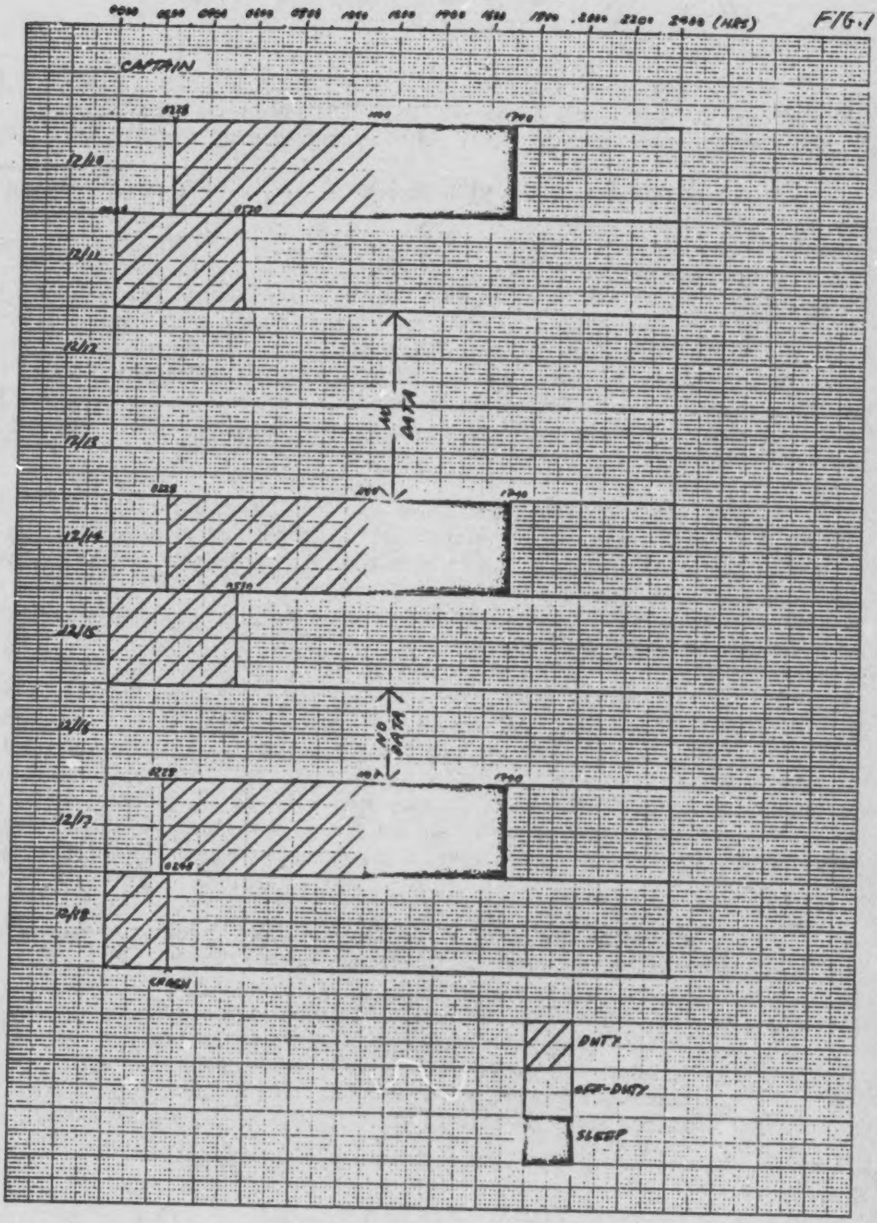
The information on exact times of sleeping, exact times of working, and exact times of meals would be very easy to obtain by an investigative team when they were interviewing the families and colleagues of the parties involved. Without this information, no definitive statement can be made as to whether circadian factors were involved in this accident. In our view, this is a serious omission in the report.

The NTSB Report also shows some unawareness of the importance of circadian factors. On Page 25, the Report states "If the flight crew made appropriate use of these rest periods, as the evidence indicates they did, fatigue should not have been a factor." However, this totally misses the important point - that rest periods made available during the individual's subjective day are much less profitably utilized for sleep and hence sleep loss can result even though a number of hours comparable to the nighttime rest period is provided.

In evaluating the prior schedules of each of the air crew members and flight controller, we note the following facts:

a. The Captain was undertaking this particular run for several cycles before the one in which the accident had occurred. We would not expect any circadian performance problem if this information is correct and, more importantly, if the Captain

FIG. 1


0000
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400 (HRS)
CAPTAIN
12/10
0225
1100
1700
12/11
0000
0520
12/12
NO DATA
12/13
12/14
0225
1100
1700
12/15
0510
12/16
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12/17
0225
1100
1700
0240
12/18
CRASH
DUTY
OFF-DUTY
SLEEP

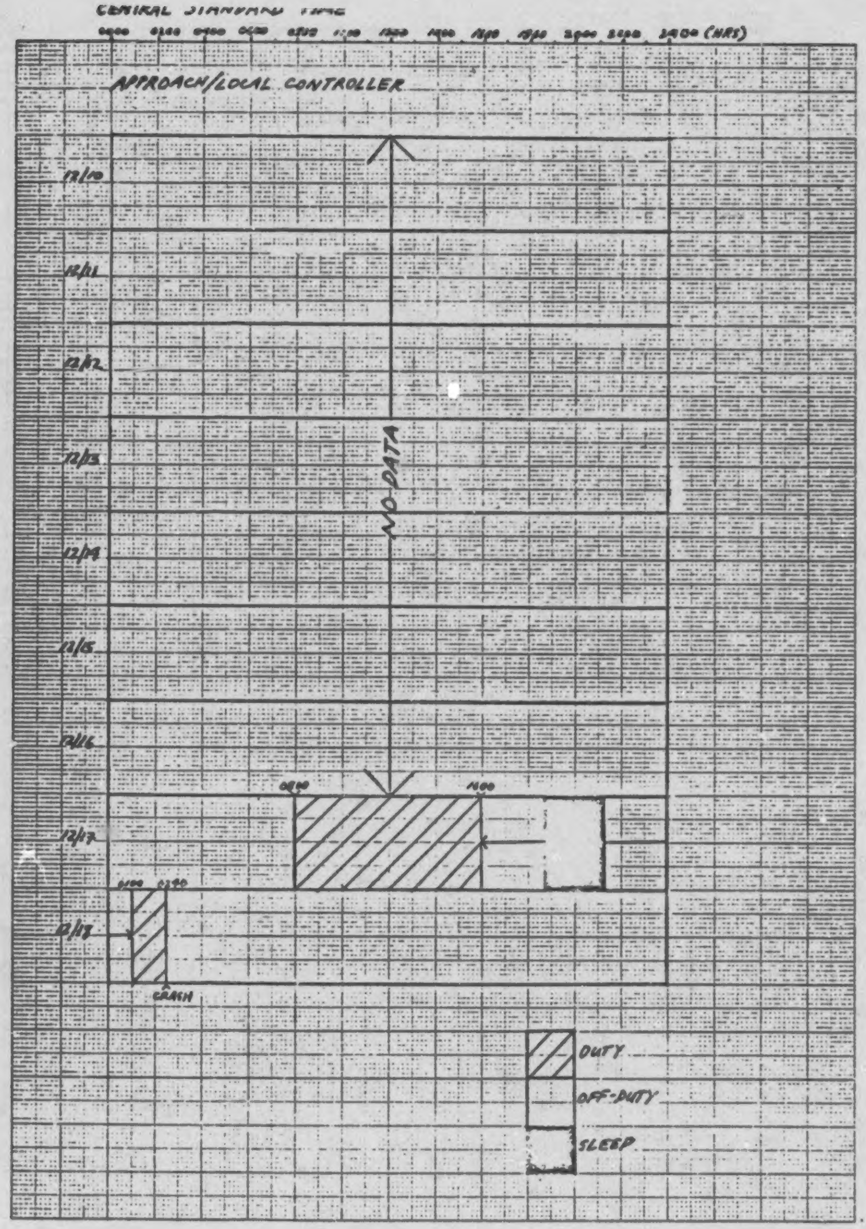
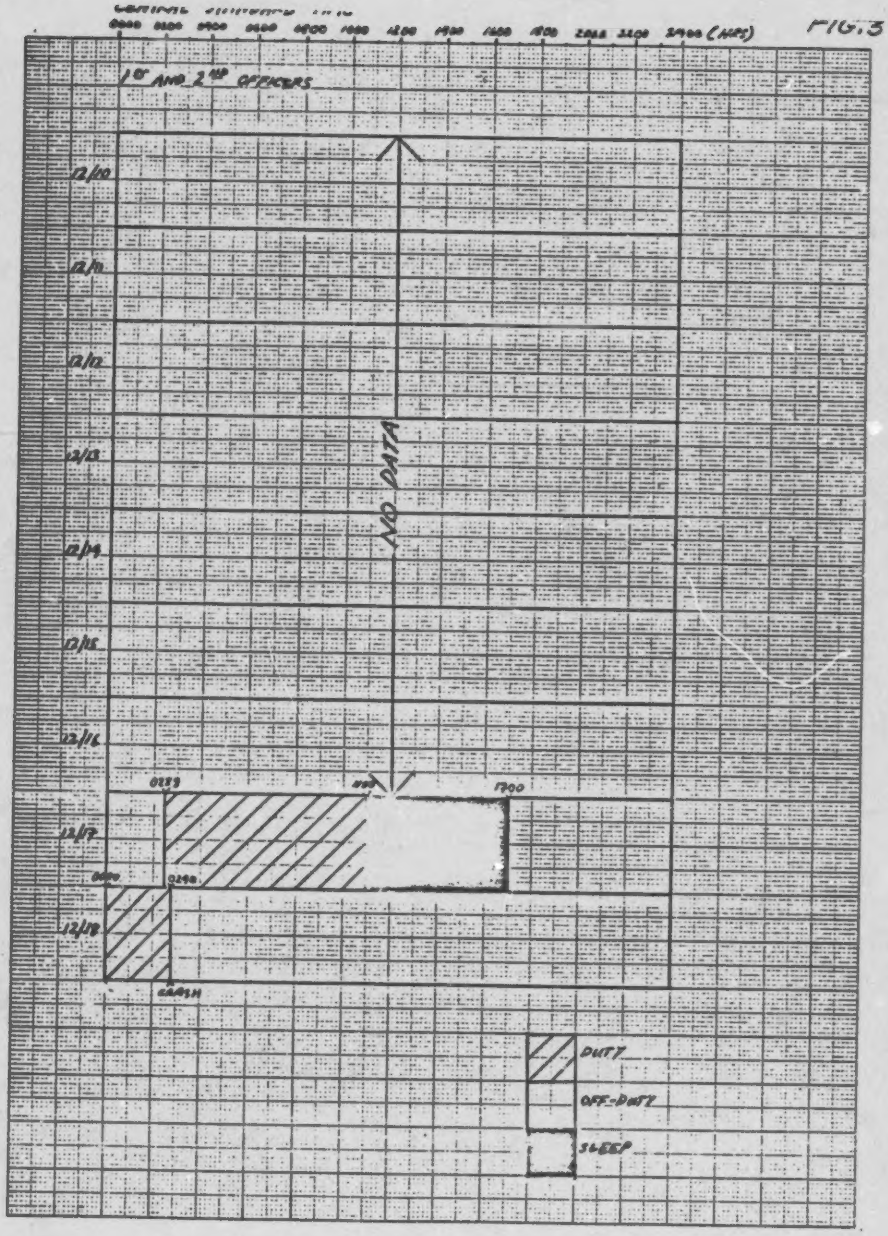

CENTRAL STANDARD TIME
0000
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400 (HRS)
APPROACH/LOCAL CONTROLLER
12/10
12/11
12/12
12/13
12/14
12/15
12/16
12/17
12/18
NO DATA
0800
1100
0100
0240
CRASH
DUTY
OFF-DUTY
SLEEP

FIG. 3


CENTRAL STANDARD TIME
0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400 (HRS)
1ST AND 2ND OFFICERS
12/10
12/11
12/12
12/13
12/14
12/15
12/16
12/17
12/18
NO DATA
0223
1100
1700
0000
0240
CRASH
DUTY
OFF-DUTY
SLEEP

had maintained the timing of sleep and wake in his off-duty days that he experienced in his on-duty days. However, the social demands of his family life might have made such a rigid adherence to a fixed shift schedule difficult.

b. We note also that the air traffic controller involved in this accident had just been subjected to both day and night shifts within a 24-hour day. He had worked the shift from 07:00 hours to 15:00 hours and then reported for duty at 24:00 hours for the night shift. It is noteworthy that during the nine hours he was off-duty, he only slept about two to two and a half hours. This observation is compatible with previous evidence (Weitzman E.D., 1970; Weitzman, E.D., 1974) showing inefficient use of rest periods for sleep when those rest periods are presented at inappropriate times in the circadian cycle. We cannot, however, fully evaluate the probable performance decrements of this controller since there is no information on the shift schedules that he was working over the previous week. Hence, if he normally worked the night shift and the 07:00 to 15:00 shift was an exception, then much less performance decrement could be predicted than if he routinely worked the day shift and this was the first instance where he had switched that week to a night shift.

In summary, because the accident occurred near the circadian minimum in performance rhythms for subjects synchronized to normal day-night cycle is not conclusive proof that this was a factor in this accident. The shift work schedules of each of the parties involved must be documented so that an evaluation can be made whether they were fully adjusted to the night shift duty, or whether they were in a situation with inadequate time to adjust.

Our evaluation of Captain Price's Model shows that the data on the timing of the schedules of the participants are reasonable. In addition, his review of performance decrements that are associated with circadian phase shifts in work and sleep schedules are compatible with experimental evidence.

However, as discussed above, there is insufficient evidence on the previous work schedules of each of the parties involved in this accident to determine whether such circadian factors played a role in this accident. This data can only be obtained from a documentation of the exact sleep, wake, duty-time, off-time and meal time data of each of the air crew and the flight controller.

## 4. RECOMMENDATIONS

a. There is considerable evidence which indicates that performance decrements may occur when work schedules of pilots and air traffic controllers are rapidly shifted so that they are required to perform at the minimum of their circadian performance rhythms. The reduced scores in a variety of laboratory and on-site tests at certain points in the circadian day do not, of course, prove that the performance decrement drops the person below the level of safe performance capability. Yet, performance above an adequate safety level is not assured either.

There is a major omission from the NTSB Report (and Captain Price's Model) in that neither provides the data to evaluate the probable circadian performance rhythms of each of the parties involved. Future examination of whether circadian performance minima can lead to unsafe levels of performance that may cause aircraft accidents must rely on complete documentation being provided for every accident that occurs so that future statistical evaluations can be made. The evidence required is the exact times of sleep and wakefulness, duty and off-duty, and meal times for ten days prior to the accident. These data are necessary for the determination of the phase of the circadian performance rhythms of each of the individuals involved.

We emphasize that the lack of data provided on this accident neither makes it possible to rule out circadian performance factors, nor indicts them as causes for this accident. There is sufficient experimental evidence to indicate that this could be a factor and it is important that it is fully evaluated for the future of aviation safety.

b. We consider it prudent that especial care be taken with planning shift work schedules for those responsible for the safety of aircraft operations. While there is insufficient evidence, as yet, to demonstrate a clear adverse effect on safety, this circadian performance factor cannot be excluded. The wisest precaution, until a full evaluation can be made, is to allow extra off-duty time before a sudden change in shift schedule, especially when there is a shift from daytime to nighttime flying, or vice versa. Adequate time must always be allowed for sleep to occur, taking into account the inefficiency of sleep at certain times of the circadian day.

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NASA Technical Memorandum 81275

# Pilot Fatigue and Circadian Desynchronosis

## Report of a Workshop held in San Francisco, California, on August 26-28, 1980

April 1981

NASA
National Aeronautics and
Space Administration

## INTRODUCTION

The workshop on "Pilot Fatigue and Circadian Desynchronosis was sponsored by NASA and was held at San Francisco, CA on August 26-28, 1980. The purpose of the workshop was to assist NASA in responding to a Congressional request* that NASA determine whether "the circadian rhythm phenomenon, also called jet lag" is of concern, "and either decide, if in fact: one, there is any valid reason to look at it; and two, what agency should be doing it."

In response to this request NASA coordinated with the FAA and other appropriate organizations and concluded that more information was needed before a determination could be made as to whether a research program is warranted for circadian desynchronosis, and if so, what it should consist of.

To assist NASA in making a determination and in pinpointing the numerous issues involved, a group of experts was invited to participate in a workshop. The program was organized by Dr. Joseph C. Sharp, Deputy Director of Life Sciences (Chairman); Dr. Alan Chambers, Chief of the Man-Vehicle Systems Research Division, and Dr. Charles M. Winget of the Biomedical Research Division, all of NASA's Ames Research Center.

The workshop participants, in their view, formed a unique group: there were representatives from the scientific community including university, military, and other federal agency scientists; and the aviation community, including airline pilots and representatives of airline management. The list of participants is given as Appendix A.

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*Hearings before the Subcommittee on Transportation, Aviation and Communications of the Committee on Science and Technology. U.S. House of Representatives, Oct. 30, 31, 1979, pp. 677-678.

Participants had been sent a list of three questions to which NASA wished answers. These were:

1. What, if any, are the pertinent issues to the aeronautical community?
2. Assuming the above discussions identify issues of substantial concern - is there hard information or knowledge available to eliminate or resolve the problem?
3. For those issues where there is a need for additional information - what current research methods and approaches will provide the needed information?

In preparation for the workshop the participants were also sent two documents.

1. The ASRS draft report entitled "Fatigue and Associated Performance Decrements in Air Transport Operations - An Aviation Safety Reporting System Study" (Contract No. NAS2-10060) by E. Gene Lyman and Capt. Harry W. Orlady, July 28, 1980.
2. The report entitled "Effects of Circadian Rhythm Phase Alteration on Physiological and Psychological Variables: Implications to Pilot Performance" (NCA2-675-005) by Daniel C. Holley, July 15, 1980.

These reports provided a bibliography relating to the subject, together with summaries of relevant literature.

The participants were divided into three committees each consisting, insofar as possible, of scientists, pilots, and management flight operations personnel. A workshop member from NASA was assigned to each committee, and acted primarily as a moderator.

Following the statement of the problem by the Chairman, Dr. Sharp, each non-NASA participant was asked to present his personal position as it related to the problems. The workshop then separated into the three individual committees to consider the first question. A plenary session followed in which each committee presented its statement. General discussion of these statements ensued. The remaining questions were handled similarly. The meeting closed with a personal statement by each of the non-NASA participants on how he viewed the three days of proceedings.

As is inevitable when such diverse expertise is represented in a single room the discussions were wide-ranging, and often exceeded the scope suggested by the three original questions. Initially, the participants seemed unsure of what was required of them, but as discussion ensued they became more enthusiastic.

The reports of the individual committees have been coalesced to reflect the thinking of the group, and will now be presented.
As has been stated, many concerns and interests were expressed during the discussions, and the original questions were expanded upon. These concerns and interests have been noted where relevant. There was general agreement on all of the issues. While unanimity was not attained, it is fair to say that the major differences of opinion concerned the severity of the problem, and the approach that should be taken to address the problem.

## STATEMENT RELATIVE TO QUESTION 1

"What, if any, are the pertinent issues to the aeronautical community?"

The initial statements made by the participants indicated that most did not perceive a major problem relating to pilot fatigue or to circadian desynchronosis as factors in air safety. As the participants received additional information from their colleagues, these views began to change, at first imperceptibly, so that by the end of the discussion of this question there was general agreement that a problem might exist. There were two major hurdles.

The use of the terms "pilot fatigue" or "fatigue" were troublesome to many, particularly those from the biomedical research community. While it was recognized that fatigue is something that can be understood by all, Classical Physiology views fatigue from the standpoint of muscular fatigue and has so studied it. Since there is no evidence that the mind becomes fatigued the term "pilot fatigue" was perceived to be of limited usefulness. Further, pilot fatigue can at present be assessed only in subjective fashion, and sleepiness and lowered arousal, etc. can be confused with fatigue. As discussion proceeded during the course of the workshop, the participants became more comfortable with the concept of "performance decrement" of pilots, as such degradation can be studied more readily than subjective fatigue and can be quantified. Thus, questions regarding the effects of fatigue could not be answered while those regarding performance could.

The second hurdle was that, to some, it was neither fair nor correct tc imply that pilot fatigue (or pilot performance degradation) was a cause of accidents, since the number of airline accidents is relatively small. It was generally conceded that such performance degradation from whatever cause could lead to an increase in the probability of aircrew errors; and, also that as the error rate increased so did the probability, however small, of an accident. The recognition that these correlations are statistical quantities rather than absolutes did much to eliminate differences of opinion, and shifted the focus to the reduction of errors. There was no disagreement whatsoever that error reduction could probably lead to statistically increased air safety.

Question 1 was answered in the affirmative, that there is a problem, that there are issues here which are indeed pertinent to the aeronautical community. Disagreement existed as to the extent of the problem.

It was agreed that extensive literature already exists which provides much evidence that fatigue is increased (or performance degraded) in association with:

1. Sleep loss or deprivation and alterations of habitual sleep/wake cycles.
2. Circadian desynchronization associated with time-zone changes and irregularity of work/rest cycles.
3. Long duty hours.
4. Other human factors such as:
    a. Long periods of low activity and lowered sensory input.
    b. Letdown/relaxation/boredom.

c. Less than optimal nutrition.

d. Use of alcohol or drugs or other non-nutritive substances used to counteract fatigue and sleep difficulty.

Obviously, many of these factors are interrelated. Night flying or time-zone changes induce phase shifts of the circadian system and result in increased sleepiness and alterations of moo

Functions altered by disturbances in biological rhythms include sleepiness, vigilance, short-term memory, task sequencing, mood, etc.

Quantification or identification of fatigue has heretofore been based on subjective measures, and fatigue cannot be readily distinguished from other sources of error, e.g., lowered arousal.

The concept of pilot-capacity/demand-onthe-pilot provides a model for estimation of the margin of safety. Pilot capacity is diminished by the factors enumerated above while demand may be constant or may increase, thus reducing the margin of safety. What cannot be stated clearly is the extent of reduction of pilot capacity (performance) by any of these factors, nor, perhaps more importantly, is much known relative to their interactions, i.e., whether they are additive or synergistic. What was agreed upon was that any of these factors or interactions could reduce performance capacity and that when the demand on the pilot exceeded his capacity the probability of an error increased.

It was apparent that the aviation system has been designed so that performance decrements lead infrequently to accidents. However, since such decrements may lead to errors and errors may lead to accidents, efforts to minimize the likelihood of decrements should be undertaken. Some specific remedies may already exist, including more optimal scheduling, improved nutrition, and by the education of pilots as to the problems they are likely to encounter, how to recognize them, and the provision of countermeasures.

The subject of individual differences or variation among pilots was much discussed. It is known that people differ as to their tolerance for irregular work/rest schedules and that some are incapable of continued shift work. It was suggested that methods that predict whether an individual could tolerate shift work would be quite useful. Some, but not enough, information is already at hand.

A contributing factor to the difficulties in identifying the problem is the lack of appropriate methodologies for studies of accidents in which fatigue or circadian desynchronization may have been a factor. Accident investigators typically have not been trained in human factors or psychology. These deficiencies may be remedied by the preparation of appropriate live operations survey/questionnaire materials.

## STATEMENT RELATIVE TO QUESTION 2

> "Assuming the above discussions identify issues of substantial concern--is there hard information or knowledge available to eliminate or to resolve the problem?"

As mentioned, there are extensive data already in existence. With regard to fatigue as a factor in unwanted occurrences in air operations there were at least 10 sources of data identified, either actual or potential:

1. Anecdotal information.
2. Captain's irregularity reports.
3. Company interviews regarding irregularities.
4. The ASRS data base.
5. Solicited information through the ASRS mechanism.
6. Derivative information from other transportation modes and basic research.
7. Military, particularly Military Airlift Command.
8. The ALPA Fatigue Survey.
9. The Iberian pilot study, nearing completion.
10. Requested pilot feedback.

Additional occurrence reports are needed as well as information on the relationship of fatigue factors (duty, recreation, rest, sleep, diet, activity, drugs) to accidents. While time-zone effects on performance are known, not much is known of the effects of low activity levels. It is easier to study the effects of these factors on performance decrement than on fatigue, per se.

Further, extensive data exist with respect to performance under various work/rest schedules. Truckers, railroad engineers, ship crews, as well as shift workers have been studied to various degrees. Research on various physiological functions which exhibit circadian rhythms has been done, and, in particular on what happens when these superimposed daily patterns are altered.

While data exist on the effects on performance of a single 16- or 18-hour tour of duty, less is known about a pilot's ability to perform throughout several such tours of duty on successive days.

There is evidence that performance is adequate following time-zone changes which do not result in sleep loss, thus re-emphasizing the role of sleep loss in reduction of performance capacity. If sleep loss is inevitable, appropriate sleep time (relative to the biological clock) should be allowed before the next scheduled flight. Recovery time should take into account the amount of sleep lost, based on known data.

The pilot should also be made aware of the cumulative effect on his performance capacity of partial sleep loss, and scheduling should be made so that partial sleep loss is minimized. Each pilot should be made aware of the potential effects of sleep loss on his performance, namely on visual motor potential skills, his ability to receive information, attention span, short term memory lapses, vigilance, etc.

What is not known are the effects on cockpit performance of losses of particular amounts and periods of sleep nor the best strategies for scheduling sleep outside of normal sleep time.

While there are data relative to circadian effects on psychomotor performance, there are few or no similar data on complex decision making performance, nor on social cooperation and interactions.

Pilots should practice good nutrition but it cannot, at this time, be stated what specific foods or diets should be recommended to mitigate performance decrements in aircraft operations.

The question of age and rate of adaptation was discussed. There is evidence from basic research that subjects over the age of 40 developed desynchronosis in temporal isolation rhythms. There is also evidence that in free running (extended periods without time indications) there are few age differences in rhythm synchronization/desynchronization, but that there are differences in sleep patterns. There have been no good phase shift studies with respect to age. It is also possible that older people may show less of a performance decrement than younger people with respect to sleep loss because they have learned to pace themselves.

STATEMENT RELATIVE TO QUESTION 3

> "For those issues where there is a need for additional information--what current research methods and approaches will provide the needed information?"

Once again, it was stressed that there is a great deal of data available already, and that, while not all of it is directly applicable, much of it may be. This information has not been used adequately to date. There was some concern as to whether data that may be collected pursuant to research projects recommended by the participants would, in fact, be used to improve regulations, or in any other way. Also, there is a fairly serious information gap between the scientific literature and the operational people who might be able to use it, and another between the scientific community and people such as passengers who might make use of information provided by scientists.

There was wide agreement that the information available needs to be digested or translated and disseminated to those who stood in need of it: pilots, air traffic controllers, cabin crew, members of regulatory bodies and the public.

During the discussions results from research, e.g., on neurotransmitters, nutrition, feeding schedules, etc., were applied to the problem at hand. These data were derived from animal studies as well as basic human studies. Other data discussed were obtained from ground-based or simulator studies. There was a pervasive feeling, however, that the hard information being sought would be obtained only from operational studies, i.e., those conducted in the cockpit environment. In order to design operational studies a number of preliminary studies need to be carried out. One such study, for example, was proposed to be conducted for 30 days of the sleep/wake cycles within an extended mission environment. Data would be collected from approximately 50 pilots. Measurements would be made at bedtime, sleep onset, time of awakening, and arising time for each 24-hour period for each pilot. These data would be correlated with flight times and duty times. Additional information would be obtained regarding subjective mood, pilot perceptions, and mission requirements. If feasible, data would also be collected on such factors as meals and alcohol consumption.

Another analogous study would be an operational test (conducted in airline cockpits) with the goal of gathering objective data on sleep disturbance and sleep deprivation, where such data would be obtained using electroencephalographic methods.

With the possible exception of improved methodologies for collecting questionnaire/survey data and, perhaps, the development of novel psychomotor and complex decision-making tasks to measure performance decrements, adequate research methodologies appear to be in place. Devices to continuously monitor heart rate, body temperature, and activity, which do not interfere with the pilot's normal daily activities, already exist. Properly used, such devices would provide a wealth of information on these biological rhythms and on their relationship to the rhythmicity of sleep.

Recognition of individual differences with respect to tolerance of altered sleep/wake cycles and rates of readaptation led to the suggestion that the two extremes of the population be studied. Are there coping mechanisms used by some, the successful adaptees, and not by others? Do the extremes differ in lifestyles?

Information furnished by the studies broadly outlined above would be vital in the design of full-fledged, and perhaps definitive, operational cockpit studies. It was also suggested that simulator studies could be helpful. Discussions centered around two as representative. One where flight crews returning from "fatigue" inducing flights would be placed in their company's training simulator for an additional "flight leg" to observe performance. This performance would then be compared to performance in simulator flights when the crews were well rested. A suggestion was made that the first of any such studies utilize crews returning from the most difficult tours of duty. The other model suggested for simulator studies focused on a systematic examination of sleep/wake histories of flight crews representative of actual live conditions. Here ground based scenarios such as those used by H. P. Ruffell Smith* were recommended. It was generally believed that before these simulator studies or other laboratory research were to be undertaken a clearer understanding of the operational flightdeck environment and its associated difficulties was necessary. The operational flight surveys should be the first step.

There was much discussion on selection of pilots for the flight studies. The use of volunteers was somewhat suspect in that they might represent a biased sample. Pilots' groups receive numerous requests for pilot participation in studies, the aims of which frequently do not seem relevant to the needs of the groups' members, and their organizations have, therefore, turned away many such requests. The pilot and airline participants felt that the aims of the studies outlined above would be supported by their organizations and strong pilot participation could be expected.

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*H.P. Ruffell Smith, A Simulator Study of the Interaction of Pilot Workload with Errors, Vigilance, and Decisions, NASA TM 78482, Jan. 1979.

# PILOT FATIGUE AND CIRCADIAN DESYNCHRONOSIS WORKSHOP

August 26 - 28, 1980

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|---|---|---|
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15. Supplementary Notes

*Report of a Workshop held in San Francisco, California, on August 26-28, 1980

16. Abstract

A workshop on pilot fatigue and circadian desynchronosis was sponsored by the Man-Vehicle Systems Research Division at Ames Research Center in August 1980. The workshop was designed to elicit the opinions of experts with regard to whether circadian desynchronosis is a significant problem in air transport flying, the magnitude of the problem, and possible ways to approach it from a research viewpoint. Workshop participants included scientists from universities, military and other government laboratories, and aviation operations specialists from the airline industry and air carrier pilots.

It was concluded that there is a safety problem, of uncertain magnitude, due to transmeridian flying and a potential problem due to fatigue in association with various factors found in air transport operations. Much information is already available in the scientific literature, but there is a clear need to "translate" this information into terms meaningful to line flight personnel. The participants agreed on a need for better, hopefully objective data regarding the sleep, activity, and other pertinent factors from pilots flying a variety of demanding schedules. Simulation studies of flight crew performance should be utilized to determine the degree of fatigue induced by demanding schedules. Further simulation studies should be performed to delineate more precisely the factors responsible for performance decrements in flight and to test solutions proposed to resolve problems induced by fatigue and desynchronosis.

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Mr. **Gore**. Our final witness on this panel is Mr. Frank Pollack, a nuclear reactor operator with Commonwealth Edison at the Quad-Cities Plant in Bettendorf, Iowa.

We welcome your appearance here, Mr. Pollack. Please proceed.

[The biographical sketch of Mr. Pollack follows:]

2236 Avalon Court
Bettendorf, Iowa 52722

319-355-1252

1-5

RESUME

of

FRANK L. POLLACK

PERSONAL DATA

Age 36, married, three children, excellent health

EDUCATION

1981 Associate of Applied Science Degree in Mechanical Engineering Technology, Scott Community College, Bettendorf, Iowa
Graduated Highest Honors

1981 Certificate of Achievement - Nuclear Reactor Technician, Joliet Junior College, Joliet, Illinois

MILITARY SCHOOLING

1967 Submarine School, 8 weeks, honorman graduate

1966 Nuclear Power Welding School, 16 weeks

1966 Nuclear Power Prototype, 26 weeks

1965 Nuclear Power School, 26 weeks

1965 Machinist's Mate "A" School, 16 weeks

EXPERIENCE

1971 to Present
Commonwealth Edison Company
Quad Cities Nuclear Power Station
Cordova, Illinois

Nuclear Station Operator, 1975 to present

- received reactor operators license in 1975.
- operate all turbine and generator equipment, monitor and control the reactor plant in all modes of operation, operate all auxiliary equipment and systems, trouble shoot plant equipment and systems, determine equipment to be taken in and out of service for maintenance.
- review and rewrite plant procedures and technical specifications.
- communication with all levels of plant personnel, construction personnel and nuclear regulatory commission representatives.

FRANK L. POLLACK

- conduct on the job training of future license personnel.
- direct shift personnel during routine operation and emergency situations.

Equipment Operator, 1974 to 1975

- high voltage switching, in and out of service work, plant trouble shooting, assist control room operators when necessary, routine testing of plant equipment.

Equipment Attendant, 1971 to 1974

- preoperational testing of equipment and systems while plant was under construction.
- electrical switching, operate plant auxiliary systems and rad-waste systems, in and out of service work, routine testing of plant equipment and systems.

## MILITARY EXPERIENCE

1964 to 1970
U.S. Navy

Machinist Mate First Class, Submarine Qualified, Honorable Discharge

- served as an assistant to the engineer by keeping engineering records, test plans and procedures.
- qualfied to stand all engineroom watches including engineroom supervisor, operated and maintained reactor and propulsion plant systems.
- supervised machinery division personnel, trained new engineering division and shipboard personnel.
- certified stainless steel welder, performed welding and nondestructive testing, maintained welding equipment and records.

## PROFESSIONAL AFFILIATION

Professional Reactor Operator Society

- quad cities nuclear station facility representative
- served on executive committee
- region III president
- member of board of directors

## PERSONAL INTERESTS

restoring Model "A" Fords, hunting, fishing, collecting antiques, gardening, civic functions.

Mr. POLLACK. Thank you, Mr. Chairman.

As indicated, I am employed by the Commonwealth Edison Co. as a nuclear station operator at the Quad-Cities Nuclear Power Station. It is located just up the Mississippi from the Quad-Cities metropolitan area near Cordova, Ill. As a licensed reactor operator, I am responsible for the safe operation of the reactor plant, the turbine and generator, emergency and auxiliary systems, and also to insure the health and safety of the public.

I am also the region III president of the professional reactor operator society.

I have over 18 years experience in the nuclear field, of which 6 years of that time was spent in the Navy in various schools and on nuclear submarines. I have worked at the Quad-Cities station for more than 12 years on rotating shifts based on a 5-week schedule.

The nuclear station operators at the Quad-Cities station have worked several types of shift schedules ranging from all three shifts in a 5-week period a modified shift preference, and to our present schedule. For various reasons, we have found that our present schedule works out best because some of us work the afternoon and day shifts and we can adapt better to that; some of us work midnight and day shifts, and some of us can adapt better to that; and others prefer to work all three shifts.

By the way, in the operating department there are five different shift schedules—I have included just one—the one the nuclear station operators work.

Some of the advantages of working rotating shifts are: More daylight time with my family; easier travel during the week; stores and places of interest have smaller crowds; more daylight hours are available for yard work, sports, and hobbies; scheduling appointments with doctors and dentists is easier; access to businesses and Government offices which are closed during the weekends.

Some disadvantages of working rotating shifts are: Inadequate amount of uninterrupted sleep—this is most difficult when working the night shift because of neighborhood noise, children, et cetera. Without adequate sleep, I feel tired, run down, short tempered, and irritable. While I am on this shift, I am unable to sleep any later than 1 p.m. Consequently, I become tired in the evening and must have an additional couple of hours of sleep before I go to work. Considering my job responsibilities, it is imperative that I have an adequate amount of sleep. My family also has to work around my sleeping schedule.

Second, I have a limited social life. The schedule I presently work requires that I work three out of every five Saturdays and three out of every five Sundays. I am entitled to approximately 10 full weekends a year off. We operators are required to work when most people receive 3-day weekends because of holidays. Also, most people look forward to their weekends. Imagine taking 80 percent or 40 of your weekends away and substituting days off during the week at a time when most family and friends are not available.

Third, it hinders further education. Some operators would like to take college courses. However, because of scheduling problems, along with loss of sleep and the additional amount of time away from family, most do not attend; or those who do, often drop out after a semester or two. It is my understanding there is a possibility of the Nuclear Regulatory Commission requiring operators to have a certain amount of college credits or a degree. Because of this possibility, I attended our local community college and did receive an associates degree. I worked mostly nights and evening shifts, rotating and switching with other operators whenever possible. This schedule lasted for about 16 months and required about 13 to 14 hours a day away from home. With the mental and physical demands placed on me during this time, along with the disruption of family life, I cannot recommend to anyone who works a rotating shift to enroll in a degree program.

As a nuclear station operator, it is absolutely necessary that I be alert and have a positive attitude at all times. The problems caused by working rotating shifts and the stress that results is only part of the whole picture. We operators have to contend with public sentiment, State and Federal regulations, utility and industrial review groups, changing plant systems and procedures, and operator requalification tests.

As a result of Three Mile Island, many modifications and additions have been made to systems and procedures. There are ongoing studies to find ways to improve the man/machine interface and operator qualifications. These studies should improve the reliability of the nuclear facilities and the performance of the operators and reduce the number of errors attributed to operators.

To my knowledge, none of the reports of operator error has specifically cited fatigue or stress as a factor. However, I believe these factors cannot be overlooked. A study of the timeframe when operator error has been reported would be beneficial. I believe the timeframe would show a pattern of night shifts and the last few hours of other shifts. I find that I must make an extra effort to stay alert during the early hours of the morning, usually from 3 o'clock to 5 o'clock. The amount of sleep that I had prior to coming on shift doesn't seem to affect this period.

I sincerely hope that my testimony sheds light on the problems faced by rotating shift workers and that it is useful in solving some of the problems. The Professional Reactor Operators Society is presently proposing a study on the effects of rotating shift work on reactor operators.

On behalf of the Professional Operators Society and myself, I would like to thank you for this opportunity to address this subcommittee hearing.

[The prepared statement of Mr. Pollack follows:]

## TESTIMONY OF FRANK L. POLLACK

My name is Frank Pollack. I am employed by the Commonwealth Edison Company as a nuclear station operator at the Quad-Cities Nuclear Power Station which is located near Cordova, Illinois. As a licensed reactor operator I am responsible for the safe operation of the reactor plant, the turbine and generator, emergency and auxiliary systems, and also to ensure the health and safety of the public.

I am the Region III President of the Professional Reactor Operator Society. I am married and have three children, ages 10, 7 and 5. We live in Bettendorf, Iowa which is a part of the Quad-Cities Metropolitan Area. Our home is 26 miles from the facility.

I have over 18 years experience in the nuclear field, of which 6 years of that time was spent in the Navy in various schools and on nuclear submarines. During this time I worked several different shift schedules. I have worked at the Quad-Cities Station for a little more than 12 years o[illegible]fts based on a 5 week schedule, except for 7 months while I was [illegible] training for my reactor operators license.

Over the years the nuclear station operators at Quad-Cities have worked several types of schedules which ranged from all 3 shifts in the 5 week period to modified shift preference, and to our present schedule (see attached schedule). Of all the shifts the operators have worked, our present schedule is the most acceptable to the majority. As indicated on the sche[illegible]

5 operators work 14 days on shift number 1, which i[illegible] night

shift, and 11 days on shift number 2, which is the day shift. Another 5 operators work 14 days on shift number 3, which is the evening shift, and 11 days on shift number 2. The last group of 5 operators rotates on all 3 shifts. For various reasons we have found that our shift preferences are evenly spread over all 3 daily shifts.

Some of the advantages of working rotating shifts are:

- I am able to spend more daylight time with my family.
- travel is easier during the week because there is less traffic.
- stores and places of interest have smaller crowds during the week, which makes shopping and sightseeing more enjoyable.
- there are more daylight hours available for yard work, sports and hobbies.
- scheduling appointments with doctors, dentists, etc. is easier.
- I am able to attend my children's daytime school activities.
- access to businesses and government offices which are closed on weekends.

Some of the disadvantages of working rotating shifts and the ways in which they have affected me and my family are:

- inadequate amount of uninterrupted sleep. This is most difficult when working shift number 1 (nights) because of daily routine neighborhood noise such as traffic, lawn mowers, children playing etc. Without adequate sleep I feel tired and rundown, short tempered and irritable, which puts stress on myself as well as my family. My family also has to work around my sleeping schedule such as my wife having to postpone any housework that would create a disturbing noise level and she is also unable to hold meetings or entertain. The children cannot have friends in to play and she is constantly reminding them that I am sleeping and that they must be quiet. For some reason while I am on this schedule I am unable to sleep any later than 1:00 p.m. Consequently, I become tired by early evening and must have an additional 2 hours of sleep before I have to leave for work. This allows little or no time during the evenings to spend with my family. Considering my job responsibilities, it is imperative that I have an adequate amount of sleep.

- limited social life. The schedule I presently work requires that I be on the job 3 out of every 5 Saturdays and 3 out of every 5 Sundays. Consequently, this gives me only 1 full weekend off every 5 weeks to spend with my family and friends. While working rotating shifts I am entitled to approximately 10 full weekends a year. We operators are required to work when most people receive 3 day weekends because of holidays, this also puts a strain on social life. Most people look forward to their weekends with anticipation and are anxiously awaiting the end of the work week on Friday. Imagine taking 80% or 40 of your weekends away and substituting days off during the week, a time when most family and friends will not be available. Church attendance is affected since I am able to participate on only 2 out of every 5 Sundays, and then if I happen to be out of town my attendance is even less. As my children become older and are more involved in weekend school functions and sports activities, I will not be able to give them the attention and support they will need. My hobby of restoring antique cars is also affected because activities such as swap meets and car shows are held on weekends, thus limiting my participation.

- hinders furthering education. Some operators would like to take job-related college courses. However, because of the scheduling problems which occur along with the loss of sleep and the additional amount of time away from family, most do not attempt to attend; or those who do try, usually drop out after a semester or two. It is my understanding there is the possibility of the Nuclear Regulatory Commission requiring the operators to have a certain amount of college credits or a degree. Because of this possibility, I attended our local community college and did receive an associates degree in mechanical engineering technology. The administration and faculty couldn't have been more understanding with regard to my schedule. However, I I worked mostly nights and evening shifts, rotating and switching with other operators whenever possible. This schedule lasted for 16 months and averaged about 13 to 14 hours a day away from home. With the mental and physical demands placed on me during this time, along with the disruption of family life and the strain put on my marriage, I wouldn't recommend anyone who works rotating shifts to enroll in a degree program.

As a nuclear station operator it is absolutely necessary that I be alert and have a positive attitude at all times. The problems caused by working rotating shifts and the stress that results is only part of the whole picture. We operators have to contend with public sentiment, state and federal agencies, utility and industrial review groups, changing plant systems and procedures, and operator requalification tests. These factors are compounded by the stress of working rotating shifts.

I sincerely hope that my testimony sheds light on the problems faced by rotating shift workers and that it is useful in solving some of these problems.

The Professional Reactor Operator Society is presently seeking ~~a~~ funding grant to study the effects of rotating shift work on nuclear reactor operators. On behalf of the Professional Reactor Society and myself, I would like to thank you for the opportunity to address this subcommittee hearing.

## OPERATORS WORK SCHEDULE 1983

| NAME | MTWTFSS | MTWTFSS | MTWTFSS | MTWTFSS | MTWTFSS |
|---|---|---|---|---|---|
| | 0222220 | 0011111 | 1100111 | 1111002 | 2TTTT00 |
| | 0011111 | 1100111 | 1111002 | 2TTTT00 | 0222220 |
| | 1100111 | 1111002 | 2TTTT00 | 0222220 | 0011111 |
| | 1111002 | 2TTTT00 | 0222220 | 0011111 | 1100111 |
| | 2TTTT00 | 0222220 | 0011111 | 1100111 | 1111002 |
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| | 0222220 | 0033333 | 3300333 | 3333002 | 2TTTT00 |
| | 0033333 | 3300333 | 3333002 | 2TTTT00 | 0222220 |
| | 3300333 | 3333002 | 2TTTT00 | 0222220 | 0033333 |
| | 3333002 | 2TTTT00 | 0222220 | 0033333 | 3300333 |
| | 2TTTT00 | 0222220 | 0033333 | 3300333 | 3333002 |
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| | 1100333 | 3333002 | 2TTTT00 | 0222220 | 0011111 |
| | 3333002 | 2TTTT00 | 0222220 | 0011111 | 1100333 |
| | 2TTTT00 | 0222220 | 0011111 | 1100333 | 3333002 |

Mr. GORE. Thank you very much. Thanks to all of you.

I am going to ask just a couple of quick questions, and turn to my colleagues, and then we will have a second round.

We have heard on this panel people representing factory workers, policemen, nurses, airline pilots, and nuclear powerplant operators, and all of them have experienced the difficulties associated with constantly rotating shift changes which are designed with no consideration of the circadian rhythms that scientists have now pinpointed.

All of you have, I think, been very eloquent in describing for us not only the effects that these problems have on you and your coworkers, but also in the case of the people who deal with the public and on whom the public relies heavily, the effects that the public can be exposed to.

If half of the policemen in the United States are walking and driving around the streets in the condition that you described, Mr. Day, then that is something that the general public ought to be concerned about, as well as police officers and police managers.

If nurses are making life-and-death decisions in a condition similar to the conditions that you described, Ms. Jones, that is something in which we ought to be interested.

Captain Stone, you mentioned your concern about the condition of pilots. As a frequent airline traveler, let me tell you that I am concerned about that, too. If a pilot is in that kind of condition when he takes the controls of the jet, no matter how good his intentions or how good his skills, if they are diminished that severely, the traveling public is put at risk.

Mr. Pollack, obviously the events at Three Mile Island were extremely complicated, but the critical nature of the decisions that you and your colleagues have to make on a routine basis—or at least be prepared to make—I think ought to lead the NRC to take this shift change problem into account. Also, I think the NTSB and the FAA should.

I would hope also that the National Association of Manufacturers and police departments and hospitals around the country would take into account the latest scientific evidence, because it is not one of these situations where, when changes are made, one side wins and another side loses; both sides win, productivity goes up, the way people feel is improved, the public gets a better performance, everybody wins.

The purpose of this hearing is really to take the realization that Gordon Thompson had and shared several years ago and match it to the scientific evidence which is now available in increasing quantity and try to make it available to those employers and employee organizations that talk about shift changes and design rotation systems, and then try to eliminate some of these problems that could easily be eliminated if the rotation schedule was designed to match circadian rhythms.

I have some specific questions that I will come back to, but I would like to recognize Congressman Skeen.

Mr. SKEEN. Thank you very much, Mr. Chairman.

I, too, think that each of you has made a very significant contribution to our understanding of what the problem is. Some of us who have never worked on alternating shifts don't really appreciate some of the problems associated with them, even though some of our work may involve minor desynchronosis.

Unfortunately, we are dealing with a problem that we cannot avoid. The requirements of some industries necessitate shift work of some kind or another. I think what we are trying to do is arrive at the least disruptire way—and I notice the word is used in almost everyone's testimony here, "adjustment" or "adaptation."—to accomplish alternating schedules. The human being is a very adaptable creature; but there is no need to make things any more difficult than necessary.

I wonder if recent research results are having much of an impact on the people who are in charge of management, scheduling, and so forth?

I have some specific questions here. I would like to first of all start with Captain Stone. In your written testimony, you refer to some accidents that were attributable in part to fatigue resulting from shift work. You also mention that the National Transportation Safety Board recommends to the Federal Aviation Administration that they expedite some rulemaking that would make flight time and duty time limitations and rest requirements for commuter air carriers the same as they are for domestic air carriers.

Have you had any response from the FAA along this line?

Captain STONE. No, sir.

Mr. SKEEN. Have they ever given any indication that they intend to respond?

Captain STONE. Not to my knowledge.

Mr. SKEEN. But you have made a request for these changes in rulemaking?

Captain STONE. Yes.

Mr. GORE. Would my colleague yield?

Mr. SKEEN. I certainly would.

Mr. GORE. FAA will be testifying tomorrow, and we will get a response of some kind or another from them tomorrow.

Mr. SKEEN. Very good, Mr. Chairman. It is going to be very interesting to see the attitude of those who do make rules, whether or not they take into account the specific problems that the witnesses brought before us today.

Before I relinquish my time could each of you describe to me the peculiar kind of shift problems in your line of work. Airline captains, I know, have one that just varies all over the board, but yet there is still a rhythm to it, as I gather; is that not true, Captain Stone?

Captain STONE. There is a rhythm to it maybe periodically on a 3-day trip.

Mr. SKEEN. Over a 3-day period or something like that?

Captain STONE. That is normal to be a rhythm. That is what we encourage in scheduling. But like any other shift where we come days off which are normal and go into a pattern where things are not normal—we would like to stay in that pattern if it is night-night-night, but many of the carriers don't do that. The pattern I described here is one where you have to shift from an early morning and, all of a sudden, now you have to sleep during the day instead of sleeping at night, and then you are back again trying to stay awake when your body wants to sleep. Then you have to sleep again to get out for an early morning trip.

That seems to be the biggest problem that I hear complaints about. If you are going to put me in a night pattern, then keep me there. But don't shift me from an early-morning departure to a late-night departure and back.

Mr. **Skeen**. That is what I was getting at. They try to establish a pattern, but then the pattern itself is an aggravation. I think it tended, as your testimony would support, to aggravate the situation rather than helping it.

Mr. Thompson, could you explain the scheduling? You said seven on, seven off, in the tire business?

Mr. **Thompson**. Yes, sir. I enclosed a graph. We work 7 days, off 2. Then you work 7 more days, and off 1; and work 7, off 4.

It seemed like when you did work—like I said, in our plant, they are very physically demanding jobs. When I was off, I couldn't enjoy any time off with my family because I had to rest so I could go back to work. It was just a constant strain.

A lot of people say, "Well, you are off 4 days." It took 4 days to get rested up.

Mr. **Skeen**. I can agree. I can see that.

Mr. Day, what type of scheduling do you have? Is yours on a daily basis, a 3-day schedule cycle, or what?

Mr. **Day**. Police departments employ a wide range of various schedules. In Prince George's County, we have toyed with several different ones over the past history. Right now, the patrol forces work on a schedule where they work 4 10-hour days, and then they have either 2 or 3 days off, depending on which shift they are moving off of. When they come back to work after that approximately 1½-day-off period, they move into the next shift in the rotation. For instance, if they work 4 days of day work, they will then have 3 days off, come back and start working 4 days of evening work; after their 4 days of evening, they will then have a couple of days off and come in for 4 nights of midnights; and then have a few days off and go back into the cycle with day work again.

I have recently moved to a less difficult shift where I simply move back and forth in an alternating way between day work for 1 week and evenings for 1 week. But the majority of the Prince George's County policemen are on what we call the 4–10 program. The thing is—it is surprising—half of them really enjoy and prefer it. There is almost an even split within our department. The other half would prefer to see something else.

I would like to point out that shift work is getting a bad rap here, perhaps. Shift work may not intrinsically in itself be bad for us. I have kind of come to the conclusion that, for some of us, shift work or rotating is perhaps more natural and more advisable. When I was working that type of weekly rotation system, I found that it was very natural and comfortable to go into the 25-hour cycle instead of the 24-hour cycle. If I had been left alone, if I could be placed in a vacuum, I might adapt that lifestyle naturally.

The problem for me, the really serious problem, developed when there were outside influences that the normal world was placing upon me that could cause me to have to disrupt the routine.

**Mr. Skeen.** But you were on one cycle, and they were on another.

**Mr. Day.** Yes. My doctor, if I have a doctor's appointment, he is going to have it in the daytime, he will not do it at 2 in the morning.

**Mr. Skeen.** You are going to have to wait anyway.

**Mr. Day.** Yes, you are absolutely right. You must know my doctor.

**Mr. Skeen.** I know all of them.

In police work, do the rookies take the bad shifts? In all of these industries, I wonder if the newcomer takes the worst? Is this part of the rationale?

**Mr. Day.** It is not intended that way, but it works out that way to an extent, though a great many veterans share his problem. The way it works out is that rookies are always placed into the general patrol force, because that is where you bite your teeth on police work for the first time. The people who really have problems with the shifts and take great steps to get out of them wind up with the specialty units, a detective unit, or become instructors at the training academy, or rise in rank where they become administrators and work all day work. Those people tend to get away from the shift work and leave the rest of us behind.

They also tend to be the power centers within the police department. They don't have the problems that the general worker has with the shift work, though they once experienced it. We sometimes think that perhaps they have lost some sensitivity to the difficulties that we in the field experience.

**Mr. Skeen.** Ms. Jones.

**Ms. Jones.** I have to agree with that for nursing. There are as many different scheduling patterns that we see in hospitals as there probably are hospitals. In my particular institution, we don't rotate shifts. We have a permanent day shift and a permanent evening shift.

**Mr. Skeen.** You can select the shift that you would like to work on?

**Ms. Jones.** Well, the choice that you have is the second or third shift. You can ask for the first shift, but that is not a common occurrence. In most hospitals that hire a permanent staff, they wouldn't have vacancies on the day shift due to seniority. So, in response to your question to Mr. Day, our rookies are on the second and third shift, and wait their turn to come to day shift if they can. If they can't, then they leave the hospital to go into an area where there is a day shift opening.

Many of the nurses on the second and third shift are there by choice due to family situations or attending school. But for the most part, I would say that nurses take those assignments because that is what is offered to them.

**Mr. Skeen.** The point I was trying to get across is that there seems to be very little in the way of free choice, which is maybe not essential to the arguments, but your shift is by assignment and you have to adapt.

**Ms. Jones.** Yes.

**Mr. Skeen.** I see.

**Mr. Gore.** Would my colleague yield on that?

Mr. **Skeen**. Yes.

Mr. **Gore**. We did a telephone survey of hospitals as well. We called 12 hospitals in 12 different cities. It wasn't a scientific sample, but 7 of the 12 had regular shift rotation for their nursing staff, and 5 were on a weekly or biweekly basis. So I think that, in this case, your permanent shifts are the exception rather than the rule for nurses; would you agree?

Ms. **Jones**. I would have to agree with that. Most of the larger hospitals especially have a rotation of shift. We are a 200-bed hospital, so we are somewhat smaller.

Mr. **Gore**. Without objection, I would like to put into the record at the appropriate point the results of the telephone survey of the police departments and hospitals which was prepared by Joe Kilner of the staff.

[The information follows:]

**MEMORANDUM**

TO: Dr. Phil Sokolove

FROM: J. F. Kilner

SUBJECT: Results of the Phone Survey on Shift Design

The following is a preliminary report on the phone survey I conducted on 21, 24, 25 January 1983 concerning shift design in hospitals and police departments in the cities you specified. The numbers preceding each line of data refer to the question number on the sheet you gave me. The data that follows is listed by city rather than by institution, however if you would like some other format I would be glad arrange it per your instructions.

Washington
Police (202) 727-4283

1. Yes, (however, one district is experimenting with permanent night shifts).
2. 8 hour shifts.
3. 6 - 8 hour shifts, (7-3,3-11,11-7 and 8-4,4-12,12-8).
4. One week rotation period, 5 "on" 2 "off", with a day to night to evening direction of rotation.

George Washington University Hospital (202) 676-8102

1. Yes
2. 8 hour shifts, (some shifts are 12 hours long in the Critical Care and Intensive Care Nursery Units).
3. 3 - 8 hour shifts, (7-3,3-11,11-7)
4. One week rotation period, 5 "on" 2 "off", with a day to night to evening direction of rotation.

Chicago
Police (312) 774-5570

1. Yes
2. 8½ hours
3. 6 - 8½ hour shifts, (7-3:30,3-11:30,11-7:30 and 7:30-4,3:30-12, 11:30-8).
4. 28 day rotation period, 6 "on" 2 "off until the shift ends on a Friday, then 3 "off". 3 "off" also occurs when the last day of the shift ends on a Saturday. Direction of rotation is day to night to evening.

University of Chicago Medical Center (312) 947-5757

1. Yes, day shift nurses rotate on an as needed basis, with evening and night nurses assigned permanent shifts.
2. 8½ hour shifts, (12 and 10 hour shifts, nonrotating, in Critical Care and Emergency Room by the choice of individual nurses).
3. 6 - 8½ hour shifts, (7-3:30, 3-11:30,11-7:30 and 8-4:30,4-12:30 12-8:30)
4. No set direction of shift rotation, but the hospital trys to allow 24 hrs. between shift changes, the duration of which may only be one shift before the nurse returns to the original shift.

Atlanta
Police (404) 658-6600
1. No
2. 8 hour shifts
3. 3 - 8 hour shifts, (7-3,3-11,11-7).
4. Usually 5 "on" 2 "off", with no rotation, Officers are assigned permanent shifts, and work other shifts only if they transfer.

Grady Hospital (404) 588-4307
1. Yes
2. 8 hour shifts.
3. 3 - 8 hour shifts, (7-3,3-11,11-7).
4. 2 week rotation period, 5 "on" 2 "off", with a day to evening or day to night direction of rotation. No evening to night rotation.

Miami
Police (305) 579-6420
1. No.
2. 10 hour shifts.
3. 3 shifts per day with the hours assigned according to the area to be covered, with the responsibility for assignment left up to the commanders in those areas.
4. No rotation except by transfer or if needed on an emergency basis.

Jackson Memorial Hospital (305) 325-6604
1. Yes.
2. 8 hour shifts.
3. 3 - 8 hour shifts, (7-3,3-11,11-7).
4. No set duration on shift or rotation direction, generally depends on the needs of the personnel, and the flexibility of the unit on which the nurse works. NOTE: This hospital refused to generalize in any fashion.

St. Louis
Police (314) 444-5603
1. Yes, but senior officers can "opt-out" of rotation.
2. 8 hour shifts.
3. 5 - 8 hour shifts, (7-3,3-11,11-7,10-6,6-2).
4. One week rotation period, usually 5 "on" 2 "off", but at times 4 "off" or as much as 7 "off" in order to ensure no more than full time. Direction of rotation is day to night to evening.

Barnes Hospital (314) 454-2000
1. Yes.
2. 8 hour shifts
3. 3 - 8 hour shifts, (7-3:30,3-11:30,11-7).
4. One week rotation period, 5 "on" 2 "off", with rotation on only two shifts at a time, day to night, day to evening or evening to night.

Detroit (313) 224-4400
1. Yes.
2. 8 hour shifts
3. 3 - 8 hour shifts, (8-4,4-12,12-8).
4. One month rotation period, no set number of days "on" and "off" schedule differs too much tomake generalization. Direction of rotation is day to night to evening.

Henry Ford Hospital (313) 876-2600

1. Yes.
2. 8 hour shifts
3. 3 - 8 hour shifts, (7-3,3-11-11-7, with some areas working 10 and 12 hour shifts).
4. One month rotation period, with no direction of rotation due to rotation through only two shifts at a time. Shift rotation is day to evening or day to night with permanent evening and night shifts.

Cleveland
Police (216) 623-5000

1. Yes.
2. 8 hour shifts.
3. 3- 8 hour shifts, (7-3,3-11,11-7).
4. One month rotation period, with at least 32 hours between different shifts. Direction of rotation is day to night to evening.

Cleveland Memorial-Highlandview Hospital (216) 398-6000

1. Yes, rotation on the day shift but permanent shifts on evening and nights.
2. 8 hour shifts, but some may work a combination of 12 and 8 hour shifts in order to cover all hours, but would not rotate if on this schedule.
3. 3 - 8 hour shifts, (6:45-3:30,3-11:30,11-7:15).
4. Normally nurses work three weeks on the day shift and the forth week will do a combination of either day-evening or day-night.

Dallas
Police (214) 670-3011

1. No.
2. 8 hour shifts, ( one division is experimenting with 4 - 10 hour shifts).
3. 3 - 8 hour shifts, (7-3,3-11,11-7).
4. Usually 5 "on" 2 "off", with no rotation.

Presbytrerian (214) 369-4111

1. No, 90% of hospital does not rotate.
2. 8 hour shifts
3. 3 - 8 hour shifts, (6:45-3:15,2:45-11:15,10:45-7:15)
4. If there is rotation at all it is on an indivdiual basis, and generally the period is one month.

Denver
Police (303) 534-2424
1. No
2. 8 hour shifts..
3. 3 - 8 hour shifts, (7-3,3-11,11-7).
4. Generally 5 "on" 2 "off".

Denver General Hospital (303) 893-7355
1. Yes.
2. 8 hour shifts, with some 12 and 10 hour shifts, which constitute only a small part of the hospital.
3. 3 - 8 hour shifts, (7-3:30,3-11:30,11-7:30).
4. Cannot make a generalization on the period of rotation, for it depends upon the unit onwhich the nurse works and the needs of that unit. The rotation direction is always day to evening or day to night, but the nurse may work several "day" and several "night" shifts in one week.

Los Angeles
Police (213) 485-2121
1. No.
2. 8 hour shifts.
3. 3 - 8 hour shifts, (7:30-4:15,3:30-12:15,11:30-8:15).
4. No regular shift rotation , but if the watch commander believes that the best interests of the departemnt can be served then he may rotate every 90 days . Senior officers may bump others off a shift as well.

Los Angeles County-U.S.C. Medical Center (213) 226-2622
1. No.
2. 8 hour shifts.
3. 3 - 8 hour shifts, (7-3:30,3-11:30, 11:15-7:15).
4. No regular shift rotation.

Seattle
Police (206) 625-2051
1. No.
2. 8 hour shifts.
3. 3 - 8 hour shifts, (3:30-11:30,11:30-7:30,7:30-3:30)
4. No regular shift rotation, 6 "on" 2 "off".

Harbor View Hospital (206) 223-5963
1. Yes.
2. 8 hour shifts, with some 12 and 10 hour shifts in CCU and ER.
3. 3 - 8 hour shifts, (7-3:30, 3-11:30,11:15-7:15).
4. Two week rotation period, with the day shift rotating through open shifts on the evening and night shifts, which are assigned permanently. Rotation direction is day to evening or day to night. The 10 and 12 hour shifts stay permanently on days or nights.

New York City
Police (212) 374-5000

1. Yes.
2. 8 hour shifts.
3. 3 - 8 hour shifts, (8-4,4-12,12-8).
4. Rotate between days and evenings on a 5 "on" one shift 2 "off" then another 5 "on" another shift, followed by 2 or 3 "off". Once every two months, (about two months), 5 "on" the night shift following an evening shift.

## APPENDIX #1

This is a summary of the master question sheet you gave me. The numbers next to the questions below correspond to the numbers in front of the data in the memo.

1. Do the nurses/policemen in your hospital/department work on a rotating shift schedule?

2. How many hours in each of the shifts?

3. How many shift changes per day, when do those shifts begin and end?

4. What is the shift rotation schedule, from the perspective of the employee? What is the duration of each shift from the perspective of the employee, and what is the direction of the rotation?

POLICE DEPARTMENTS

| CITY | ROTATION? | INTERVAL |
|---|---|---|
| Washington,D.C. | Yes | 7 days |
| Chicago, Ill. | Yes | 28 days |
| Atlanta, Ga. | No | ---- |
| Miami, Fl. | No | ---- |
| St. Louis, Mo. | Yes | 7 days |
| Detroit, Mi. | Yes | 1 month |
| Cleveland, Oh. | Yes | 1 month |
| Dallas, Tx. | No | ---- |
| Denver, Co. | No | ---- |
| Los Angeles, Ca. | No | ---- |
| Seattle, Wa. | No | ---- |
| New York, Ny. | Yes* | |

Of the twelve Police Departments surveyed, six (6) used rotating schedules for patrol officers, while the other six (6) were staffed primarily with officers on permanent shifts. The six (6) departments with rotating schedules all rotated shifts in a "forward" or "advancing" manner, (in other words; dayshift to nightshift to eveningshift), however 4 of those departments negated the deleterious effects of that "advancing" rotation by extending the time each officer spends on one shift before rotating to one month or more. The remaining six (6) police departments were staffed by officers assigned to permanent shifts, removal from which occurs only by individual choice or administrative fiat.

HOSPITAL NURSING SCHEDULES

| CITY | ROTATION? | INTERVAL |
|---|---|---|
| Washington, D.C. | Yes (d to n to e) | 7 days |
| Chicago, Il. | Yes, as needed | ---- |
| Atlanta, Ga. | Yes, (d-e or d-n) | 2 weeks |
| Maimi, Fl. | Yes, no general pattern | ---- |
| St. Louis, Mo. | Yes, (d-e or d-n or e-n) | 1 week |
| Detroit, Mi. | Yes, (d-e or d-n) | 1 month |
| Cleveland, Oh. | Yes, (3 wk days, 1 wk d-e or d-n) | 1 month |
| Dallas, Tx. | No | ---- |
| Denver, Co. | Yes, (d-e or d-n) | 3-4 days |
| Los Angeles, Ca. | No | ---- |
| Seattle, Wa. | Yes, (d-e or d-n) | 2 weeks |
| New York, NY. | Yes, as needed | ---- |

All but two (2) of the hospitals surveyed employed rotating shift schedules for nursing personnel. Among those using rotating shifts, two (2) hospitals scheduled shift changes in one month intervals. Another three (3) hospitals rotated nurses on an "as needed" basis for which no average interval could be determined. An intermediate group of two (2) hospitals used two week rotation intervals, and finally three (3) hospitals used one (1) week or less rotation intervals. Seven of the ten hospitals employing rotating

HOSPITAL NURSING SCHEDULES

PAGE TWO

shifts required nursing personnel to rotate through just two (2) rather than all three (3) shifts. This technique, as well as increased rotation intervals serves to off-set some of the deleterious effects of rotating shifts.

* - This hospital had an unusual variation on shift rotations; nursing personnel were required to rotate between dayshift and eveningshift for two months, after which they worked one week of night shift, supplementing the compliment of nurses hired for permanent nightshift.

Mr. **Skeen**. Mr. Pollack, you mentioned in your testimony problems with nuclear powerplant operators because of the requirements of shift change, such as time to take courses in furthering their education, and so forth.

Is there an attempt to make an accommodation with the management and powerplant operators, and so on? I should probably ask them, but I would like your viewpoint.

Mr. **Pollack**. At present, there is none.

Mr. **Skeen**. There is none.

Do you stay with the schedule and forget about making changes?

Mr. **Pollack**. That is right. It was up to me to trade with my fellow workers, which also put a stress on them, in order to attend school.

Mr. **Skeen**. Is there much of this type of accommodation that goes on amongst workers?

Mr. **Pollack**. Pardon?

Mr. **Skeen**. Is there much of this type of accommodation between workers?

Mr. **Pollack**. Between our fellow workers, yes, it all depends. But then they also have things that they have planned and I have to work things out with them. There are times when their requirements come first. When they can change, they will change.

Usually the operators that change will change for a better schedule. For instance, when I traded when I was going to school, the school that I attended only offered the courses that I needed to take during the day shift. So all my day shifts that I would have had to adjust myself to the normal routine and spend more time with my family, and so on, I had to give up those shifts to work afternoons or midnights. I did that, as I indicated, for 16 months.

Mr. **Skeen**. Thank you. Thank each and every one of you. I appreciate that.

Thank you, Mr. Chairman.

Mr. **Gore**. Congressman McCandless.

Mr. McCandless. I was quite interested in the comments made by the representative of the Pilots Association. I might say, Mr. Chairman, it sounded like I was right at home with terms like shift differential, "4-10" and so forth. I used to negotiate contracts for the County of Riverside as a part of the memorandum of understanding. So I understand the terminology that is being used here.

We talk in terms of this one example that you gave us—five stop, and then a deadhead, and then back with a four stop, and so forth—which would consume approximately how many days or hours from the time you left your base point until the time you returned to that base point and were free to do whatever you wished?

Captain Stone. I think that particular rotation, as we'll call it, was probably in the neighborhood of about 60 hours from the time you departed your home domicile to the time you returned.

Mr. McCandless. Sixty?

Captain Stone. Sixty hours. I think it is the equivalent of three and a half days.

Mr. McCandless. In a 30-day period, if you drew that particular route and you were the pilot or a member of the crew involved, how many times would you make that trip?

Captain Stone. Mr. Babcock says that is really a 3-day trip, so it is probably close to the 60 hours that I said. But normally, that would be what we call 3 on-3 off, except that you would have another extra trip so that you would fill it up to 75 hours during the month, or 85 hours as this particular carrier is flying right now. Again, you would probably fly 5 of these, which would be 15 days on and 15 days off.

Mr. McCandless. For purposes of our discussion, during a 30-day period if you were to fly this route, you would fly it 5 times during this 30-day period?

Captain Stone. That is correct.

Mr. McCandless. And you would have a minimum of 3 days off between trips?

Captain Stone. I think that would be normal.

Mr. McCandless. Another part of the process that you live in is the seniority system. My understanding of it is that the pilots, as they become seniors in the airline, can choose the types of routes that they wish to fly.

How would you equate this kind of a trip as to seniority? Would you say this would be one of the junior pilots, intermediate pilots, or what, in terms of desirability and availability to a pilot?

Captain Stone. In our seniority, you move in blocks. You become very senior in a position and then, all of a sudden, you become very junior in the next position. For instance, take myself as an example. I, as a 727 Captain, bid for the 767. I went from a very senior 727 Captain a now junior 767 Captain. That is the way you hold yourself in blocks. A second officer, our flight engineer, he moves through the equipment in progression, but you also move through the various seats, so that you go again from a very junior up to senior, and then back to junior again.

So it is very erratic, and it occurs all through your career that you are changing. Probably anywhere from a 2-year to a 5-year cycle you are changing.

Mr. McCANDLESS. This trip that you outlined would appear to me to be a 737 or a 727 or a DC-9 type of trip; is that correct?

Captain STONE. It is a Boeing 727.

Mr. McCANDLESS. Now that you are a senior there, you wouldn't have this kind of a flight, would you?

Captain STONE. Not unless you chose to do it. We have the right to choose.

Mr. McCANDLESS. So if you were No. 1 in that category, and you didn't particularly want this kind of a flight for some reason, you could choose a much more favorable flight.

Captain STONE. That is correct.

Mr. McCANDLESS. Now you move to the 767 and you are the junior pilot there, but you are not subjected to this type of a flight because of the applicability of the aircraft; do I have the right idea?

Captain STONE. No, because now I am subjected to it in a new airplane. I no longer can choose to not fly that because I am now junior.

Mr. McCANDLESS. Well, a 767 wouldn't have five stops or four stops, would it?

Captain STONE. I don't know why not. I am flying one now. I just flew one the other day that goes to Atlanta to Tampa, Chicago, back to Tampa, to Atlanta.

Mr. McCANDLESS. I guess what I am trying to get around to here is to arrive at an assumption that may be erroneous—let me throw it out on the table—that the more difficult routes—and you have used one as an example—usually fall into categories where there are junior pilots whose ages are such that they would, by their physiology, be more adaptable to it than pilots as they become senior, given the assumption that all of the pilots enter the system at approximately the same age.

Would you comment on that assumption.

Captain STONE. The only fallacy in that is you can get three junior positions being filled, a captain, a first officer, and a second officer, who fly the late-night trip, and they are all junior, except those fellow range in age depending where they are on the seniority list. So you would normally have a young fellow, probably one who has been recently hired in the last 4 or 5 years, the second officer. You have the first officer, who has probably been with the airline 10 to 15 years, and then the captain who has been with the airline maybe 20 or 25 years.

So you do, even on those late-night bad trips, have junior people, and you can still have a wide range in age. All the captains are, like myself, old guys.

Mr. McCANDLESS. I don't think you are too old. You look pretty young to me.

Mr. Day, I was very interested in the shift arrangement that you outlined where you rotated weekly through the process of the swing, graveyard and day, if you call them that.

Mr. DAY. Yes, sir.

Mr. McCANDLESS. I found that quite different from what my experiences are on the west coast. It was found at a very early period, some 15 years ago, in many of the jurisdictions that if you were going to retain the officer and he was going to perform in an alert manner that you had to give him some type of a standard time line for his profession, his private life and recreational activities. The result was that if there was going to be a shift transfer it took place maybe quarterly during the year.

Are we an exception to that rule? Do they practice that back here?

Mr. DAY. Yes, sir. Various police departments employ a lot of different ones. When I was a Baltimore City policeman, we had a three-shift rotation, but it occurred monthly, and it was much easier to pattern your life in order to accommodate family and accommodate exercise and things of that nature.

Here in Prince George's County, they do it on a weekly basis. Some police departments even have permanent shifts. For instance, I know a Dallas police officer, and he is permanently assigned to the midnight shift and he enjoys it.

Part of the problem is that different people respond to the shifts in different ways. Some people prefer rotating shifts and some people prefer fixed shifts. I don't think you are going to ever get uniformity in our industry as far as the shifts are concerned.

Your committee is looking at things that might be done to improve the situation or correct some of the problems. I would like to throw a couple of ideas out to you.

One thing that I feel is that if it is inevitable that people get on shift work and have to be employed in this fashion, some kind of accommodation should be made by the institutions to be as little disruptive of them as they can be. For instance, where policemen are concerned and you have court scheduling, the court should really make a very strong concerted effort to see to it that court is always arranged for when the officer is on the day shift as opposed to arranging court for him when he is in the period of his cycle when he is sleeping during the daytime. These are some ways that government institutions can accommodate the shift worker if it is necessary for the shift worker to continue to work that shift work.

Also, some alternative shifts might be considered. My personal feeling is that a permanent midnight shift with the other two shifts alternating is really a very desirable sort of proposition. I think that the real problem with rotating shifts really centers around the midnights. Personally, I don't think most people have a great deal of difficulty adjusting to a certain period of time working day work and a certain period of time working evenings. The problem centers on the midnight shift. That is the one that throws you out completely.

I think that employers or governments who set up shift systems for their workers should try to, if at all possible, create one block of time, one 8-hour block, where the worker will never work so that you keep it to a two-shift rotation if that is necessary, give him some period of time he can always bank on "Those are the hours that I will be sleeping." That way he can adjust the other aspects of his life much more easily.

But in the police field, there is an awful lot of difference of opinion. I am sure there probably is in the scientific community, too. I really don't think you will get uniformity in our industry any time soon.

Mr. MCCANDLESS. I guess, Mr. Chairman, I am wondering as I listen to the testimony including that of our nurse representative, why better shift scheduling has not already been implemented. Riverside County has a hospital that I have been involved in for a number of years that has already done so.

I would like to ask, as a new member of this committee and the Congress, how we—as a subcommittee—can help resolve some of these issues?

Mr. **Gore**. Let me say briefly that there are some Federal agencies such as the FAA and the NTSB, the Nuclear Regulatory Commission, for which we have direct responsibility. We intend to inquire into how they are facing this problem with respect to municipal workers, factory workers, nurses, and airline pilots. For those who don't come under the jurisdiction of some Federal agency, our intention is to try to see that they have available to them the results of the latest scientific studies.

We have no intention of passing legislation to require a set pattern of shift changes. But I do think that it is important that the results of the scientific research be made available because there are a couple of simple rules that will benefit both management and employees if they are followed.

First, there should be rotation by phase delay, for example, from day to evening to night. Second, there should be a longer time between rotations so that people have an opportunity to adapt and are not constantly jumbled up in the midst of this circadian confusion. All of our witnesses have testified as to the difference between a weekly shift change and a monthly change.

If we can disseminate that information and get it more widely available, I am confident that the adjustment mechanisms in our economy will work better because there is a productive advantage from taking advantage of these scientific discoveries.

Mr. **McCandless**. Just one more question, if I may. A great deal of controversy centers around in the public sector of the 4/10 work week, 4 days, 10 hours a day, in lieu of the 5 days, 8 hours a day. If any of you have any comments on it, I would certainly be interested in hearing them.

Mr. **Day**. The Prince George's County Police Department works 4/10, has worked it for 5 years, and I worked it for that period of time. Generally speaking, those of us who worked those shifts found them to be, on the whole, pretty agreeable. We don't like—many of us, at least—having to switch from one shift to another. But the aspect of working 4 days 10-hours a day is something that has met with overwhelming approval by the workers. We very much enjoy having the additional time off. We found that the extra 2 hours a day that we are working has not caused any noticeable effect as far as our alertness or our ability to function at normal acceptable levels.

So we, as a police force, at least as far as the workers are concerned, are very much impressed favorably with the 10-hour day as opposed to 5 day, 8 hours a day.

Mr. **McCandless**. Ms. Jones, do you have anything to add?

Ms. **Jones**. I don't have any personal experience with the 4 day, 10 hours a day work week. We don't do that in our hospital, and I don't know of any that do. But there have been some that have tried it and have gone back to the traditional 5 day 8-hour day. I do know one in New York that did it that way. I don't know what their reasoning was.

I think that with more research into the effects of the lengthening of the day, the fatigue factor, since we are dealing with life and death situations, we would have to have some more data to go by to see what the effects of that two-hour increase in that work day are. Then the continuity of care because we are dealing with the same patients day after day. If you have 3 days off and then come back, the condition changes so widely or there are different patients, so the continuity is disrupted with a longer period of time off.

Mr. McCANDLESS. Mr. Pollack, do you have any comments?

Mr. POLLACK. Yes. Being a nuclear plant operator, it is kind of hard—and we are supposed to be manned 24 hours a day—it is kind of hard to divide 24 by 10 and come out with something workable.

However, there are a number of operators in the nuclear industry looking into the possibility of working a 12-hour day, for instance, 3 days in 1 week working a 12-hour day and 4 12-hour days in the following week. This way we are able to work our 40 hours per week, but it is averaged over a 2-week period of time. However here again we run into problems with contracts, with management, with, I guess, certain Federal and State agencies that say that we can't put in more than 40 hours a week, and so on.

So if we could go to something like this, it may be beneficial to us, but we would need some sort of legislation that would allow us to do this. At the present time, the Nuclear Regulatory Commission doesn't really want us working over 8 hours a day.

Mr. McCANDLESS. I would like to thank all of you for sharing your thoughts with me.

Thank you, Mr. Chairman.

Mr. GORE. Congresswoman Schneider.

Mrs. SCHNEIDER. Thank you, Mr. Chairman.

I would like to add on to your comments which were made earlier in point of clarification as to the fact that this investigation does relate to science and technology, for which I support and am enthused about. The information that we are garnering here today is to be used in a variety of different ways, as the Chairman says, but also for the purposes of justifying some of our research in certain aspects of the science budget.

As we are going through our budgetary process right now, we see that there is an inclination to reduce the funds that are being appropriated for the social sciences. I think that the information that we are gathering here will help us to verify the fact that this is a very valid area of research that it is not getting enough attention by the private sector.

I think that we can all recognize that the whole discussion of shift work is really a labor and management issue.

Just out of curiousity, I would like to see a show of hands from the witnesses, how many of you have raised the issue of ill health or jeopardizing the health and welfare of the people you work with? How many of you have raised that with your management?

[Show of all hands.]

Mrs. **Schneider**. I wonder what the response has been. Has there been actual change in procedures? Has there been action or just words? Mr. Pollack, maybe you can respond to that.

Mr. **Pollack**. There really hasn't been any action on it. We are governed by labor contracts, and so on, and we also have, like I mentioned before, to be manned 24 hours a day. So there really isn't much they can do about it. Our schedules are pretty much left up to the union to decide what we want to work.

At our particular plant, it is left up to each individual group. Whatever we feel is the best, then that is what we work, as long as there is somebody there 24 hours a day.

Mrs. **Schneider**. But your union hasn't really carried the water for you, so to speak, on this issue?

Mr. **Pollack**. Right.

Mrs. **Schneider**. OK.

Mr. **Pollack**. Basically, it is just us. We have decided this is what we want. As I indicated earlier, within the operating group at our station, there are five different schedules. The one that I attached to my testimony is only one.

Mrs. **Schneider**. How about in order to streamline this process? If I could see a show of hands of how many of you have received action as a result of your recommended changes to the management.

[Show of four hands.]

Mrs. **Schneider**. Good. So labor and management does seem to be working all right, despite the lack of scientific information to reinforce your cause.

Ms. **Jones**. May I make a statement here?

Mrs. **Schneider**. Yes.

Ms. **Jones**. I represent management in my institution. I am the vice president for Nursing Services and, as such, the chief nursing officer of our hospital. I initiated looking at our scheduling because of the high absentee rate we were having on the night shift, and because what appeared to be a higher incidence of medication errors on the nurses' sixth and seventh day of working any shift, not just the second and third shift. We have made some changes in our schedule after some discussion with the staff according to their preferences, but also according to some of the information that we have garnered from our unsophisticated research with the resources that we have, just the survey type things that we have done. Management took the initiative, at least in our institution, to do some of this ourselves.

Mrs. **Schneider**. OK.

Yes, Mr. Day.

Mr. **Day**. With the Prince George's County Police, we have done a great deal of research. Our psychological services unit has done a very detailed study of the effects of our current schedules on the police officers. Our Police Chief, John McHale, has publicly spoken in favor of finding some alternative to what we are working now. He believes that there are more beneficial shift systems that we could work.

Part of the problem, as far as the labor-management relationship, though, is that because our rank and file seems to be about evenly divided over the advisability of retaining the current shift schedule, the labor organization is placed in the situation where they are not absolutely certain what the membership wants at this point. That is one of the difficulties that we are running into.

Also there are some factors which are larger than management is capable of dealing with, governmental factors. Budgetary problems sometimes interfere with them doing what they would like to do in terms of the health of the workers. Such things as problems in court scheduling, if you have people constantly on midnight shift without rotating back into day work, you are going to absorb tremendous overtime costs for court compensation for those workers.

Some of those considerations interfere with the easy cooperation between the two sides.

Mrs. SCHNEIDER. Thank you very much for that insight.

Mr. Thompson, I wonder if you could elaborate a little bit—I would like to get into some of the health effects of the shift changes. When you thought it was necessary to take sleeping pills to assist you in resting a little bit better, who prescribed those pills for you? Was it the plant doctor, or was it your personal physician? Exactly who was it?

Mr. THOMPSON. It was my personal physician. It was on the 12 to 8 shift when I had real problems sleeping. I would get maybe 1 or 2 hours of sleep and that was it. I couldn't adjust. Some people can adjust and some can't. I couldn't.

Mrs. SCHNEIDER. How about your loss of taste? Did you also mention that to your doctor in conjunction with your difficulty in sleeping?

Mr. THOMPSON. Yes, I did, but there is not too much you can do. When you work 12 to 8, midnights, what kind of food do you eat when you come home? Do you eat beans? Do you eat eggs? Anything you eat doesn't taste right.

Mrs. SCHNEIDER. Thank you, Mr. Chairman. Those are all the questions I have.

Mr. GORE. Thank you.

Congressman Reid.

Mr. REID. I have no questions, Mr. Chairman.

Mr. GORE. OK. I have just a couple or three or four.

Gordon Thompson, when you were having difficulty adjusting to the rotating shift, did you discuss it with the plant manager?

Mr. THOMPSON. Yes, I did.

Mr. GORE. This may have been asked before, but what kind of reponse did you get?

Mr. THOMPSON. My personal response was that they weren't going to change the shift.

Mr. GORE. Yes.

Mr. THOMPSON. Like I said, things got so poor—the production, the absenteeism—it all got so poor that it was necessary for the company. They really didn't have any choice. So, finally, after 3 years, it was changed.

Mr. GORE. Mr. Day, are you aware of specific examples where sleepiness or lack of alertness jeopardized the health or safety of the police or members of the public?

Mr. DAY. I have not been personally involved in any cases where there was any significant adverse result to the public. There have been many, many occasions when I or other police officers I have known have had to simply park the car and actually sleep on the midnight shift, which obviously is not to the public's benefit.

I would point to an incident which occurred in Baltimore City several years ago where a police officer died in his patrol car from carbon monoxide poisoning. Apparently, he and his partner had stopped at a location—they were very tired—and they were catching some rest, and the carbon monoxide built up in the passenger compartment of the car. One officer died and the other was very seriously affected. Those are examples that are perhaps extreme.

Mr. **Gore**. What hour of the day was that?

Mr. **Day**. I understand this was on the midnight shift.

Mr. **Gore**. On the midnight shift.

Mr. **Day**. Yes.

There are many other situations where I have caught myself while driving a vehicle in a state that I really did not feel was appropriate.

Mr. **Gore**. Yes.

I would like to thank each one of you for your testimony.

Again, we are not taking the position here that shift work has to be eliminated. The point is that there are some simple rules that could be followed in designing shift rotations that would take into account the new discoveries about the human body's natural clocks or circadian rhythms, and if those simple rules were followed, the disruption in the lives and job performance of the people who work rotating shifts would be substantially lessened. Again, it is the kind of change where everybody would benefit and no one would lose. So if we could get broader recognition and acceptance of these simple scientific rules, perhaps it will do some good.

In the specific cases involving the Nuclear Regulatory Commission and the Federal Aviation Administration, as well as some other Government agencies—U.S. Navy, U.S. Army, for example, and maybe some others—we may have a more direct responsibility to see to it that these simple rules are taken into account in design of shift rotation, and we will pursue that.

Let me thank all of you for appearing here today, and particularly my two fellow Tennesseeans—especially my neighbor and friend who started this whole ball rolling. I want to thank you all for coming. Thank you.

We will go now to our second panel. This is a very interesting panel because we have a case study of a factory that contacted scientists and came up with a way to adapt these simple scientific rules to their shift rotation, and the results were, as we will hear, dramatic.

Let me call to the witness table Mr. Preston Richey, production manager with Great Salt Lake Minerals & Chemicals Corp. in Ogden, Utah; Scott Nielsen, an hourly employee with Great Salt Lake Minerals & Chemicals Corp.; and Dr. Charles Czeisler, director for the Center for Design of Industrial Schedules in Boston, Mass. Doctor, I apologize for mispronouncing your name earlier. It must have been jet lag since I have been traveling. You are also assistant professor of medicine with the Division of Health Policy Research and Education at Harvard University.

Without objection, the prepared statements of all three witnesses will be included in full in the record, and we would invite you to proceed with your presentations, beginning with you, Mr. Richey. Welcome. Please proceed.

[The biographical sketch of Mr. Richey follows:]

## BIOGRAPHICAL SKETCH

## PRESTON L. RICHEY

| | |
|---|---|
| WORK EXPERIENCE - | CURRENTLY EMPLOYED AS MANAGER OF PRODUCTION FOR GREAT SALT LAKE MINERALS & CHEMICALS CORPORATION (GSL). HAVE HELD THIS POSITION FOR FIVE YEARS.<br>PREVIOUS INDUSTRIAL POSITIONS INCLUDE GENERAL FOREMAN, PROCESS ENGINEER, RESEARCH TECHNICIAN, AND PILOT PLANT OPERATOR. |
| EDUCATION - | OBTAINED A BS DEGREE IN CHEMISTRY IN 1971. |
| PERSONAL - | THIRTY-THREE YEARS OLD, MARRIED WITH SIX CHILDREN, A SCOUT MASTER. |

## STATEMENTS OF PRESTON RICHEY, PRODUCTION MANAGER, GREAT SALT LAKE MINERALS AND CHEMICALS CORP., OGDEN, UTAH; SCOTT N. NIELSON, HOURLY EMPLOYEE, GREAT SALT LAKE MINERALS AND CHEMICALS CORP., OGDEN, UTAH; AND DR. CHARLES A. CZEISLER, DIRECTOR, CENTER FOR DESIGN OF INDUSTRIAL SCHEDULES, BOSTON, MASS., AND ASSISTANT PROFESSOR OF MEDICINE, DIVISION OF HEALTH POLICY RESEARCH AND EDUCATION, HARVARD UNIVERSITY, CAMBRIDGE, MASS.

Mr. RICHEY. Thank you.

Late in 1980, Great Salt Lake Minerals & Chemicals Corp. was confronted with a union election drive. GSL is a relatively small company and has always felt that it could deal with the needs of its people directly. As manager of production, it was my job to explain GSL's position to the hourly work force, as well as to determine what problems had led to consideration of union representation in the first place.

A series of some 25 meetings were held with crews of 8 to 12 people attending each meeting. In these meetings, I would take 20 to 30 minutes to explain the company's position on the union drive, and then spend the rest of the time discussing the specific concerns of the individuals. These meetings would frequently go for 3 hours. I kept notes on the problems expressed and found that most of the concerns were individualized problems that only applied to two or three individuals or perhaps a crew of people. However, there were two broad areas of dissatisfaction. These were poor communications and shift work.

The complaints on shift work were the most poignant. Over and over, I heard in various different ways the ills of rotating shift enumerated. Family problems, disrupted sleep, fatigue, indigestion, and downright despair were recounted graphically. I could appreciate these problems since I have worked a lot of shift work myself. However, having worked various shift schedules, I was convinced that the one we were using was as good as we were going to get. This was my stock answer to complaints about the shift schedule. But the more I was forced to give this answer, the less comfortable I became with it.

Ultimately, I decided to do my own search to determine the best schedule. I tried the library, technical publications from the Government, and industrial engineering handbooks, all to no avail. I was amazed at the dearth of substantive information on the subject. Although there were numerous effects of shift work, I could find none that would tell me how to ameliorate these effects. About this time, I ran across and article in the local paper citing Dr. Charles Czeisler as a researcher on shift work. I called him and, after some negotiation, we retained his company to redesign our shift schedules. The changes made were not particularly dramatic, but the results were. Schedule satisfaction increased dramatically, turnover dropped, and productivity improved.

We at GSL are sold on the concept of matching shift schedules to the fundamental circadian rhythms. We feel we have been able to take a significant step forward in improving the life of the shift worker, and we look forward to future advances in this field.

[The prepared statement of Mr. Richey follows:]

## TESTIMONY OF PRESTON L. RICHEY

Late in 1980, Great Salt Lake Minerals & Chemicals Corporation (GSL) was confronted with a union election drive. GSL is a relatively small company (350 people), and has always felt that it could deal with the needs of its people directly. As Manager of Production, it was my job to explain GSL's position to the hourly workforce, as well as to determine what problems had led to consideration of union representation in the first place.

A series of some 25 meetings were held with crews of 8-12 people attending each meeting. In these meetings I would take 20-30 minutes to explain the company's position on the union drive, and then spend the rest of the time discussing the specific concerns of the individuals. These meetings would frequently go for 3 hours. I kept notes on the problems expressed and found that most of the concerns were individualized problems that only applied to 2 or 3 individuals or perhaps a crew of people. However, there were two broad areas of dissatisfaction. These were poor communications, and shift work.

The complaints on shift work were the most poignant. Over and over, I heard in various different ways the ills of rotating shift enumerated. Family problems, disrupted sleep, fatigue, indigestion and downright despair were recounted graphically. I could appreciate these problems since I have worked a lot of shift work myself. However, having worked various shift schedules, I was convinced that the one we were using was as good as we were going to get. This was my stock answer to complaints about the shift schedule. But the more I was forced to give this answer, the less comfortable I became with it.

Ultimately, I dediced to do my own search to determine the best schedule. I tried the library, technical publications from the government, and industrial engineering handbooks, all to no avail. I was amazed at the dearth of substantive information on the subject. Although there were numerous articles on the harmful effects of shift work, I could find none that would tell me how to ameliorate these effects. About this time, I ran across an article in the local paper citing Dr. Charles Czeisler as a researcher on shift work. I called him and after some negotiation, we retained his company to redesign our shift schedules. The changes made were not particularly dramatic, but the results were. Schedule satisfaction increased dramatically, turnover dropped, and productivity improved.

We at GSL are sold on the concept of matching shift schedules to the fundamental circadian rhythms. We feel we have been able to take a significant step forward in improving the life of the shift worker, and we look forward to future advances in this field.

Mr. **Gore**. Thank you very much.

Before going to questions, we would like to hear from the rest of the panel. I would call next on Scott Nielsen, an hourly employee at the same company. Welcome.

[The biographical sketch of Mr. Nielsen follows:]

## BIOGRAPHICAL SKETCH

## SCOTT N. NIELSEN

WORK EXPERIENCE - Currently employed as an Hourly Harvest Foreman for Great Salt Lake Minerals & Chemicals Corporation (GSL). Have held this position since December, 1982.

Began working for GSL September 27, 1972 as a Heavy Equipment Operator Trainee and worked my way up over the past 9½ years to my present position. Was previously employed by Ogden City.

MILITARY - Joined the United States Navy on July 21, 1967 serving until July 20, 1971. Was honorably discharged as a Second Class Dental Technician.

PERSONAL - Thirty-four years old, married with one daughter, love the outdoors.

Mr. **Nielsen**. Thank you, sir.

My name is Scott N. Nielsen. I am 34 years old. I have been married for 15½ years, and I have been employed at Great Salt Lake Mineral & Chemical Corp. for 9½ years.

During my time at GSL, I have seen many different types of shift schedules implemented and abandoned for one reason or another. There are two changes that really stand out in my mind.

No. 1, the time we changed from 2 shifts a day, 6 days a week, to the 3 shifts a day which was 7 days a week. This consisted of 7 straight days of day shift, 8 a.m. through 4 p.m., Saturday through the following Friday. Then we had what we called a long change. This consisted of Friday afternoon from 4 p.m. off through to the following Wednesday night at midnight. At midnight Wednesday, we went to the graveyard shift which was midnight to 8 a.m.

through the next Tuesday morning at 8 a.m. Even though I worked this shift for a number of years, it is still confusing to me, even at this time. Then we would have Tuesday and Wednesday off and we would have to be back to work at 4 p.m. Friday afternoon. There were another 7 days straight from 4 p.m. until 12 a.m. until the following Thursday at 12 a.m.

Now this is the same schedule that Mr. Thompson described for you in his earlier testimony. Then we would have 1 day off and start the schedule all over again.

This is the schedule that we followed for more years than I care to remember. Everything on this schedule seemed to go fine until I was on the graveyard—or on the night shift, as Dr. Czeisler prefers to call it. Then it seemed everything got all screwed up. It really disrupts your metabolism. For instance, have you ever craved bacon, eggs, and beer at 10 p.m. and pizza and coffee at 4 a.m.? I have. Have you ever gone to bed hungry and woke up wanting sex instead of the other way around? I have. Have you ever had your bowels do a double somersault in midstream, stop and say to you, "Just which way do you want us to move, Jack?" I know this sounds far-fetched, but it isn't.

Social life is another story completely. For a person who works shift work, a good social life is almost nonexistent. How many times will someone invite you to some sort of function when all you can say is, "Gee, I'd love to," and be able to make it if it weren't this weekend, but maybe 3½ weeks from yesterday? Not many times. You have to let go of many of your old social contacts, give up a lot of activities many take for granted, such as bowling, dancing, bridge, dinner parties with friends, and political involvement within the community. You are forced to find new interests and activities that can be worked around a shift work schedule. As for myself, I have found new and varied interests such as snowmobiling and photography. I also set up a small shop to tinker around in. I do basically things I can do on my own because, generally, I have to spend my spare time by myself.

Family life is strained at best. There are times, even on my present schedule, that there might be 5 days during which I won't have any contact at all with my daughter. My wife works from 8 a.m. to 5 p.m., so contact with her on the graveyard shift consists of 1 hour at night, if she wakes up, then 30 minutes in the morning before she leaves. But it has helped us to place a premium on the time we do have together. So, in a sense, there are some benefits to shift work after all.

The second change in our schedule that I remember well is our change from the 7-day rotation shift, which required four crews, to the schedule we are presently on requiring only three crews. We were approached with a new idea. We were asked to participate in a study in which we were asked to keep track of our daily sleep schedules. Of course, as with any new idea, it was met with a certain amount of skepticism and doubt, myself included. After listening to the new concept and studying it, most of the people decided that it didn't really look at all that bad. As a matter of fact, it looked like there just might be some good points to it. We decided to give it an honest try.

The new schedule was set up in such a way that it only required three crews instead of the old four. Each man had 2 days off in a row, which drifted 1 day later each week. This was due to the fact that a workweek now consisted of 6 days instead of the old 7. Every 6 weeks, we have two 3-day weekends which come back to back. So that was considerably better than our old schedule.

There was one aspect of this new schedule that looked very promising, at least to me personally. It was called the slow drift week. When changing from one shift to another, each crew would work 8½ hours instead of the usual 8 hours per shift. This meant that each day, the starting time was 1½ hours later than the previous day. At the end of 5 days, you had slowly drifted into the next shift. This sounds great—right in step with your body clock. Unfortunately, that is not quite how it worked out. Many of us found this to be quite confusing. Questions came up like, "What time to we have to be here tomorrow? What time do we get off?"

Another question was, "My 2 days off are right in the middle of the slow drift. What time do I have to come back in in 3 days?" Some people showed up early, others came in late. Once in a while, some wouldn't even show due to the confusion. We complained about this the first time we went through a slow drift, and we were asked to give it another try. In the meantime, they said they would study the problem and complaints.

We tried it again, but the same thing happened. After some debate and discussion, it was decided to try to make the change from 1 shift to another in 1 day. This meant having just crews each work a 12-hour shift. The grave or morning shift would work from 11 p.m. to 11 a.m., and the usual day shift would come in at 11 a.m. and work through to 11 p.m. The crew that had been on the swing or the afternoon shift would start at 11 p.m. and would work until 7 in the morning. This set every crew up on the next later shift.

The only drawback to this was that it meant that the crew that was going from the swing to the graveyard lost 1 day of work during the shift change week. Almost everyone agreed that since this only happened every 9 weeks, a day missed 2 or 3 times a year is a lot easier than the slow drift week we had gone through before. On the week that you might miss a day's pay, GSL made it possible for those who wanted to to make up the lost hours with overtime. This system, I feel, has worked out quite well. Of course, there are always those who are against change just because it is a change. But over the last two years, everyone seems to have accepted the idea.

In the last 2 weeks, I have been talking with my fellow workers trying to get some input to help me prepare for this statement. I have found that everyone has said pretty much the same thing. They like it a lot better than the old schedule. Some said that it seemed like they had a lot more time to do the things that they wanted to, instead of just eat, sleep, and go to work. I asked them why. The response was that they have a chance to get used to a shift and can get by on a lot less sleep, which gives more free time.

I know that the attitude improvements have been great. Morale has stayed consistently high. When morale is high, production is high. Another thing that I have noticed since the schedule change is the amount of interdepartment bickering and back-biting has come to a complete stop, at least in the department that I work in.

I would like to take this opportunity to express my gratitude to the committee for allowing me to be here today.

Thank you.

Mr. GORE. Thank you very much.

I appreciate you going to the trouble to talk to your coworkers to do a kind of an informal survey in preparation for the hearing.

[The prepared statement of Mr. Nielsen follows:]

## TESTIMONY OF SCOTT N. NIELSEN

My name is Scott N. Nielsen. I am 34 years old and have been employed at Great Salt Lake Minerals & Chemicals Corporation (GSL) for 9-1/2 years.

During my time at GSL I have seen various shift schedules implemented and abandoned for one reason or another. There are two changes that really stand out in my mind:

1. Our change from two shifts a day, six days a week. This consisted of seven straight days of day shift, 8:00 am to 4:00 pm, Saturday through the following Friday. We then had a "Long Change" which consisted of being off Friday afternoon at 4:00 pm through the following Wednesday night at midnight. Graveyard shift would be midnight Wednesday to 8:00 am through the next Tuesday morning at 8:00 am. We then had Tuesday and Wednesday off and had to be back to work 4:00 pm Friday afternoon to work another seven days straight, 4:00 pm to 12:00 am until the following Thursday at 12:00 am. We then had one day off (Friday) and started the schedule all over again.

This is the schedule we followed for more years than I care to remember. On this schedule everything seemed to go fine until I was on graveyard, then it seemed everything got all screwed up. This really disrupts your metabolism. Have you ever craved bacon, eggs, and beer at 10:00 pm and pizza and coffee at 4:00 am? Well, I have. Have you ever gone to bed hungry and woke up wanting sex? Well, I have. Have you ever had your bowels do a double somersault in midstream, stop and say to you "Just which way do you want us to move, Jack?" I know this may sound far-fetched, but it is not.

Social life is another story completely. For a person that works shift work, a good social life is almost non-existent. How many times will someone invite you to some sort of a function when all you can say is "Gee, I'd love to, and would be able to make it if it weren't this weekend, but maybe 3-1/2 weeks from yesterday would be fine. You have to let go of many of your old social contacts, give up a lot of activities many take for granted, i.e., bowling, dancing, bridge, dinner parties with friends, and political involvement in the community. You are forced to find new interests and activities that can be worked around a shift work schedule. As for myself, I have found new and varied interests such as snowmobiling and photography. I also set up a small shop to tinker around in.

Family life is strained at best. There are times, even on my present schedule, when there might be five days during which I won't have any contact with my daughter. My wife works 8:00 am to 5:00 pm, so contact with her on graveyard shift consists of one hour at night, if she waits up, then 30 minutes in the morning before she leaves. But it has helped teach us to place a premium on the time we do have together as a family. So perhaps in a sense there are some benefits to shift work after all.

2. The second change in our schedule that I remember well is our change from the seven day rotation shift, which required four crews, to the schedule we are presently on requiring only three crews. These three crews were approached with a new idea. We were asked to participate in a study in which we would keep track of our daily sleep schedule. Of course, as with any new idea, it was met with a certain amount of skepticism and doubt, myself included. After listening to the new concept and studying it, most of the people decided that it didn't look all that bad. As a matter of fact, it looked like there just might be some good points about it. We decided to give it an honest try.

The new schedule was set up in such a way that it only required three crews instead of four. Each man had two days off in a row, which drifted one day later each week. This was due to the fact that a work week now consisted of six days instead of seven. There were always two days off in a row. Every six weeks we'd have two, three day weekends off back to back. There was one aspect of this new schedule that looked very promising. It was called the "Slow Drift" week. When changing from one shift to another, each crew would work 8.5 hours instead of the usual 8 per shift. This meant that each day the starting time was 1.5 hours later than the previous day. At the end of five days you had slowly drifted into the next shift. This sounds great -- right in step with your body clock. Unfortunately, that's not quite how it worked out. Many of us found this to be quite confusing. Questions came up like "What time do we have to be here tomorrow?" or "What time do we get off?" Another question was "My two days off are right in the middle of the slow drift, what time do I come in three days?" Some people showed up early, others came in late, sometimes one or two didn't show up at all due to confusion. We complained about this the first time we went through a slow drift and were asked to give it one more try; in the meantime, they would study the problem and the complaints.

We tried it again, but the same thing happened. After some debate and discussion it was decided to try making the change from one shift to another in one day. This meant having just two crews each work a 12 hour shift. The grave, or morning shift, would work from 11:00 pm to 11:00 am and the usual day shift would work 11:00 am to 11:00 pm. The crew that had been on the swing or afternoon shift would start at 11:00 pm and work until 7:00 am. This set every crew up on the next later shift. The only drawback to this was that it meant the crew that was going from swing to grave lost one day of work that week. Almost everyone agreed that since this only happened every nine weeks, a day missed two or three times a year was a lot easier to handle than the slow drift. On the week that you might miss a day's pay, GSL made it possible for those who wanted, to make up the lost hours with overtime. This system, I feel, has worked out quite well. Of course there are always those who are against change just because it's change. But over the last two years, everyone seems to have accepted the idea.

In the last two weeks I have been talking with my fellow workers trying to get some input to help me in preparing for this statement. I have found that everyone has said pretty much the same thing. They like it a lot better than the old schedule. Some said that it seemed like they had a lot more time to do the things that they wanted to do, instead of just "eat, sleep and go to work." I asked why? The response was that they have a chance to get used to a shift and can get by on a lot less sleep which gives more free time. I know that the attitude improvements have been great. Morale has stayed consistently high. When morale is high, production is high. Another thing that I have noticed since the schedule change is the amount of interdepartment bickering and backbiting has come to a complete stop.

I would like to express my gratitude to this committee for the opprotunity to appear here today. It has been a great personal experience for me. Thank you.

**Mr. Gore.** Thank you very much.

Dr. Czeisler, you are the scientist the company consulted in order to come up with a better rotation schedule for Mr. Nielsen and his fellow employees. You are a researcher in this area, and we are excited to hear from you.

Please proceed.

**Dr. Czeisler.** Thank you very much, Mr. Chairman and members of the subcommittee.

My name is Dr. Charles Czeisler. I am an assistant professor of medicine at the Harvard Medical School, a senior fellow in health policy at Harvard's Kennedy School of Government, and director of the Center for Design of Industrial Schedules.

I would like to note at the outset of this testimony that we have just entered the second century since Thomas Edison opened the first powerplant in Manhattan in 1882, making available for the first time a steady and reliable source of power throughout day and night.

Since then, there have been tremendous technological advances to develop machines which would use that electric power around the clock, but relatively little progress in overcoming the human limitations of those who operate such machines 24 hours a day, 7 days a week. In fact, high personnel turnover, high rates of accidents and illness, low morale, and low productivity plague almost all shift work operations. Yet, in this country, one out of four working men and nearly one out of six working women has a variable work schedule, including both day shifts and night shifts. Modern technology has really upset the apple cart.

In the past 100 years, a mere instant on the evolutionary time scale, the temporal environment to which mankind as a species is exposed, has been completely disrupted. The question then is, At what cost? No one knows for sure what are the long-term health consequences of rotating shift work schedules, but animal studies suggest that a 5- to a 20-percent shorter lifespan may be associated with weekly shift changes.

But there are also more immediate costs. The often monotonous jobs associated with the continuous monitoring of sophisticated equipment in many military and industrial operations are especially sensitive to the sleep loss and time-of-day effects which result from intermittent nightwork.

It is well known that human performance varies with the time of day.

[Slide.]

**Dr. Czeisler.** The first figure illustrates how the average response time and the average detection rate on a sonar performance task varies throughout the 24-hour period. The black dots on that figure represent the daily cycle of body temperature which you can see varying with the time of day, and the dash lines represent the performance on the sonar performance tasks.

I would like to ask you to note that the major decrements in performance most often occur at the trough or the low point of the daily cycle of body temperature, usually at around 5 to 7 a.m. every day, which is where those dots are at their lowest point in the daily cycle.

Lest you think that such results only apply to sonar operators, I must point out that the hazards of working at night do not stop at the factory door.

[Slide.]

Dr. **Czeisler**. The second figure illustrates a risk familiar to all of us, the hazards of driving at night. This graph demonstrates a ninefold increase in the frequency of truck accidents at around 5 a.m. as compared to daytime hours. This is when our body temperature, performance, and alertness cycles are at their low point, despite the fact that the number of drivers on the road at that time is much lower than it is during the daytime.

[Slide.]

Dr. **Czeisler**. The third figure shows the results of a continuous recording.

Mr. **Gore**. Excuse me, but could you go back to that last one briefly?

Dr. **Czeisler**. Yes.

[Slide.]

Mr. **Gore**. The exposure graph is the number of people on the road at those times; is that right?

Dr. **Czeisler**. The number of people on the highway at that time, whereas this indicates the number of accidents as a function of the time of day at various points in the cycle. You can see that the rate of accidents here is at its high point, ninefold higher than it is during the daytime, when corrected for the changes in the exposure levels at those different times of day.

Mr. **Gore**. OK; thank you.

[Slide.]

Dr. **Czeisler**. The next slide——

Mr. **McCandless**. Mr. Chairman.

Mr. **Gore**. Mr. McCandless.

Mr. **McCandless**. Going back to that last graph, when we talk about that period at 5 a.m. when you have the most truck accidents, when you arrived at the numbers that you have for that graph, was there any research into the number of hours that that driver had actually been at the wheel of that truck prior to the actual accident?

Dr. **Czeisler**. As you know, the regulations governing the scheduling of truck drivers are not very systematic in this country, and many truck drivers operate their own rigs and essentially operate at whatever hours that they choose to drive.

I don't believe that this data was compiled actually from Harris in an article published in 1977. I don't believe that there is any information on the number of hours that a particular driver has been driving at the time of an accident.

Mr. **McCandless**. My point being that I am certainly sympathetic to the position you are trying to put over, but I think that your comments about the fact that truck drivers do have that kind of latitude, that many of the truck accidents early in the morning are a result of fatigue created by the number of hours rather than the time of day.

Dr. **Czeisler**. Certainly there are many contributing factors which would contribute to any given accident. But it has been well documented that delays in answering calls, errors in reading meters, a variety of other tasks which are performed throughout the 24-hour day on regular shifts, the error rates peak at that same time of day, which is the trough, as I said, of these other physiological functions that we are able to measure.

Mr. **McCandless**. Thank you.

Thank you, Mr. Chairman.

[Slide.]

Dr. **Czeisler**. The next figure shows the results of a continuous recording during experiments on night driving conducted in Germany. This the electroencephalogram, as recorded from the brain waves, and these are the eye blink durations at this portion of the graph.

What I will draw to your attention are the numerous areas of alpha activity in the brain waves which are associated with eye closure and drowsiness while this particular individual is driving a car on the German autobon expressway for several hours during the night. He gets on to the autobon at this portion of the experiment and gets off of the autobon at this portion in a specially equipped car that is able to monitor these different functions.

What you will see here, and I will draw special note to your attention, is that for a full 20 minutes, from minute 100 to minute 120 in this particular study, there were no eye blinks and the EEG activity on the brain waves is indicative of sleep or a nap period during that portion of the driving episode.

This napping by all EEG criteria occurs while the person is driving the car on the expressway. I would like to suggest that these may be contributing to the higher rates of accidents and injuries which are occurring at time of day, these episodes that do not fit into any category that we understand as being either sleep or wakefulness because, by EEG criteria, by all of the physiological criteria that we know, they are correlative of sleep, and yet the person is still able to function at some level in order to drive a car during that period.

Mr. **Gore**. That reminds me of what Gordon Thompson said about witnessing people standing up operating a complicated and dangerous piece of machinery and seeming to be asleep on their feet.

Dr. **Czeisler**. That is exactly the point that I am trying to make.

What I would like to ask Mr. Chairman, is whether this same thing is happening in the cockpit or at the controls of a nuclear reactor. Unfortunately, up until this time, our regulatory agencies in this country have been afraid to ask that question. Researchers in Sweden have used this same technique to document that train drivers fall asleep on one out of every six night runs, keeping full pressure on the accelerator pedal and oblivious to red stop signals during these nap episodes. I am sure that many in this room can recollect similar experiences of slowly drifting off the road onto the shoulder of an expressway before being startled awake by gravel under the tires. Unfortunately, circumstances, both on the highway and in the control room, are not always so forgiving.

What can be done? Well, in 1976, we discovered that the biological clocks of patients with certain types of sleep disorders could be reset, thereby ridding them of their insomnia. This made me realize that it should be possible to design work schedules to which it would be easier for people to adapt.

Our results in the research laboratory have clarified the mystery of why shift workers who are awake for longer than normal periods often can't sleep well when they finally get home at night—or in the daytime, as the case may be. They often suffer from sleep loss, persistent fatigue and lack of alertness on the job.

It turns out that the ability to sleep and the efficiency of sleep depends on what time of your biological day that you try to go to sleep. Sleep taken during the daytime is quite different than that which is taken at night.

When Mr. Preston Richey, whom you have already heard from this morning, first contacted me in 1980 and described to me the work schedule which they were operating at Great Salt Lake Minerals, I realized that their schedule, the most common type in U.S. industry today, flew in the face of everything we knew about how our biological clocks tick.

In order to determine whether the concepts which had developed in the laboratory would ring true in the workplace, Dr. Richard Coleman, Dr. Martin Moore-Ede and I constructed a confidential survey questionnaire and administered it to all the hourly workers at the Great Salt Lake Minerals Co. The results of this initial baseline survey are illustrated in the next figure.

[Slide.]

Dr. Czeisler. Panel A in the upper left indicates that, as we predicted, nearly 70 percent of the rotating shift workers had a moderate to severe problem with poor quality sleep. Despite the fact that these workers were operating heavy equipment, nearly one-third of the workers admitted to actually falling asleep at work, as indicated in the second panel.

Ninety percent of the rotating shift workers complained that the schedule changed too often, as indicated in panel C, which is in the upper right-hand corner, which is understandable, considering that 85 percent of the rotating shift workers reported that it took a half a week or longer to adjust their sleep time following their weekly rotation. That is in the lower panel.

Based on that information, in applying circadian theory, we decided to change the direction of shift rotation such that successive shifts should progress to later hours rather than advancing to earlier hours. Nearly three out of four of the workers at GSL preferred this new direction of shift rotation based on biological data, as compared to their prior schedule. Furthermore, there was a 27-percent improvement in a subjective health index based on doctor visits, health complaints, and so on.

[Slide.]

Dr. Czeisler. Finally, the last figure demonstrates the marked improvement in the performance of the workers following the educational sessions which we administered and the introduction of the new work schedule. The rate of potash harvesting from the evaporation ponds rose 12 percent in the first quarter after its introduction, followed by a 22-percent rise in the second quarter, and a 32-percent rise in the third quarter, as compared to the same respective quarters over the previous 2 years.

The encouraging results of the Great Salt Lake study indicate that the application of circadian principles to the workplace could indeed be very productive, even at this preliminary stage in our understanding of the mechanisms which control the timing of the sleep-wake cycle.

Mr. Chairman, you mentioned that there were simple rules which could be adopted in order to try to introduce some of these concepts into the workplace. While this is so, we are still in our infancy at this stage. We still have the training wheels on the bicycle, and a lot more research needs to be done in order to further improve these kinds of schedules.

First of all, the exact solutions are going to have to differ in other settings. Airline pilots simply can't adopt this kind of schedule and neither can nurses, neither can interns and residents, and neither can a variety of other situations which wouldn't exactly apply. However, the basic principles and the techniques which we used to go about introducing these changes should remain the same. Certainly these kinds of results justify increasing our efforts to characterize the properties of the circadian timing system in man as recommended by this Institute of Medicine report, which also recommended the encouraging applications research to try to see how this work could be more systematically applied to the workplace.

There must, however, be a closer collaboration in research efforts between agencies such as the Nuclear Regulatory Commission or the Department of Defense and the physiologists and the physicians undertaking this research. It must be supported at a major level. There is currently no systematic effort being mounted to address this pressing need.

This report to the new U.S. Nuclear Regulatory Commission, for example, states, "Loss of operator alertness...must be viewed as one of the most consequential performance shaping factors in the nuclear power plant operations." This report to the Air Force Office of Scientific Research says that, "Research is needed to provide the sleep wake cycle information needed to design duty-rest schedules which least disrupt the sleep-wake cycle and minimize deteriorations in alertness and performance." Yet, instead of stimulating action, these reports are simply collecting dust on library shelves.

Gentlemen, we cannot continue to perpetuate this misuse of human energy and talent. The time has come to dust off these reports and focus our research efforts on solving the problems associated with shift work. Failure to cope with these factors may be the Achilles heel of modern military and industrial technology placing all of our society's round-the-clock activities, from national security to the generation of nuclear power, in unnecessary jeopardy.

Thank you very much.

[The prepared statement of Dr. Czeisler follows:]

TESTIMONY OF PROFESSOR CHARLES CZEISLER ON: BIOLOGICAL RHYTHMS AND SHIFT WORK SCHEDULING, BEFORE THE SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY, U.S. HOUSE OF REPRESENTATIVES.
Washington, DC 23 March 1983

Mr. Chairman and Members of the Subcommittee:

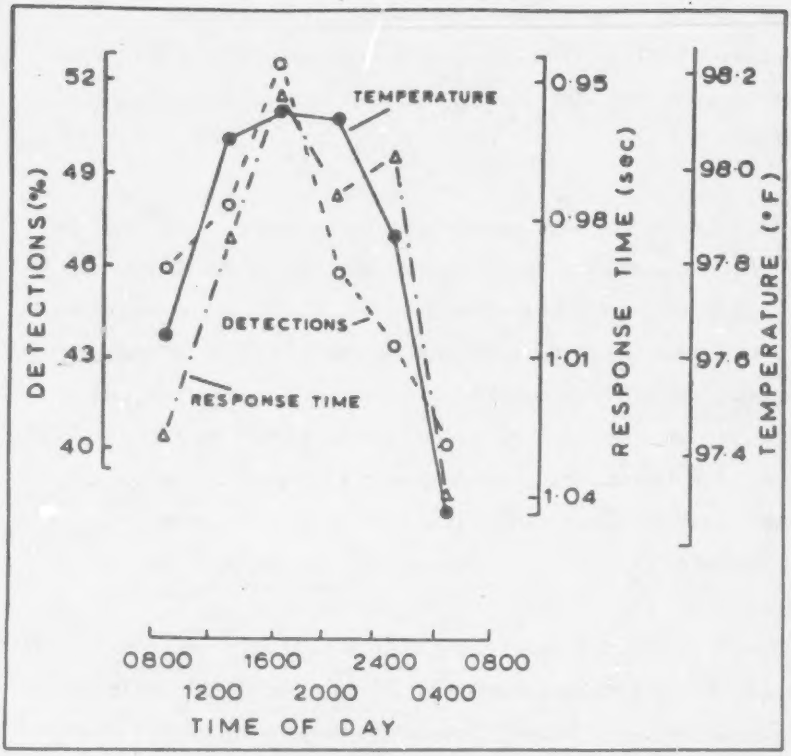
My name is Dr. Charles A. Czeisler. I am Assistant Professor of Medicine at the Harvard Medical School, Senior Fellow in Health Policy at Harvard's Kennedy School of Government and Director of the Center for Design of Industrial Schedules.

It is a pleasure for me to appear before the Subcommittee in response to your request for testimony regarding our recent research on the impact of shift work scheduling on the health, alertness and performance of workers in round-the-clock operations. It is worthy to note at the outset that we have just entered the second century since Thomas Edison opened the first power plant in Manhattan in 1882 and thereby made available a steady and reliable source of power throughout day and night. Since that time, there have been tremendous technological advances in the development of machines capable of USING that electric power round-the-clock, but relatively little progress in overcoming the human limitations of OPERATING those machines 24-hours a day. This failure to cope with human factors may be the Achilles heel of modern industrial and military technology.

The monotonous jobs associated with the continuous monitoring of sophisticated equipment are especially sensitive to the sleep loss and time of day effects which result from intermittent night work. Despite potentially grave consequences of operator errors or accidents due to the fatigue of both night duty and extended duty scheduling, the development of countermeasures and techniques to minimize deteriorations in alertness in performance has not progressed apace with technological achievements. This is probably because both management and labor alike have come to accept as inevitable the hidden costs of round-the-clock work scheduling that put too great a strain on the human organism.

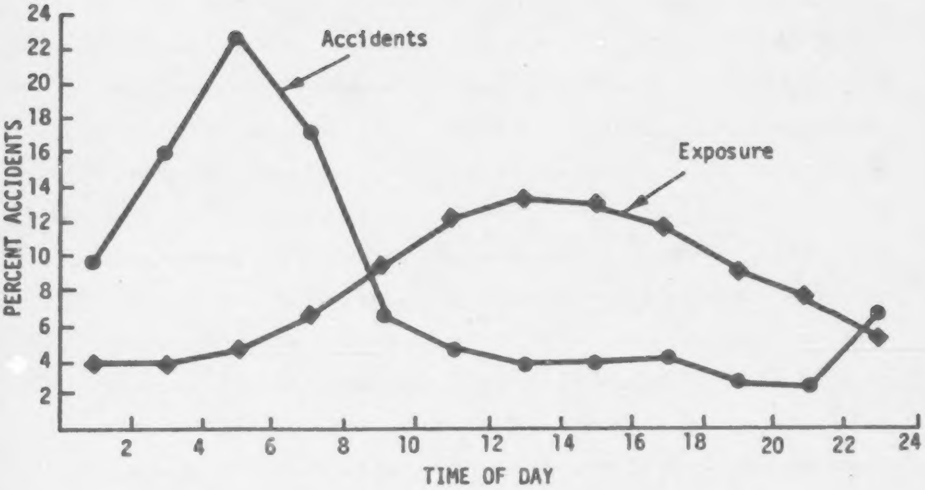
It is well known that human performance varies with the time of day. The first figure illustrates how the average response time and average detection rate on a sonar performance task varies throughout the 24 hour period (Figure I). This also demonstrates that the timing of the daily cycle of performance on this relevant task is correlated with the approximately 24-hour circadian rhythm of body temperature in man. It should be noted that the major decrements in performance most often occur at the trough of the daily cycle of body temperature, which is typically at around 5:00 to 7:00 a.m. every day in individuals who habitually sleep between midnight and 8:00 a.m.

Lest you think that such results only apply to sonar operators, I must ask each of you to realize that the hazards of working at night do not stop at the factory door. The second figure illustrates a risk to which most all of us have been exposed: the hazards of driving at night (Figure II). This graph demonstrates a ninefold increase in the frequency of truck accidents at 5:00 a.m. as compared to daytime hours. One might first suppose that darkness is the explanation. Yet even though it is also dark at midnight, the frequency of truck accidents is only slightly greater at that time than it is during daytime hours. In fact, the greatest number of truck accidents are occurring during the latter half of the night, when our body temperature, performance and alertness cycles are at their nadir, despite the fact that the number of drivers on the road at that time is much lower than it is during the daytime. The third figure illustrates why this might be so. It shows the results of a continuous



Mean detection rate and mean response time in the sonar task, and mean body temperature in sessions held at different times within the 24-hour period. (From Colquhoun et al., 1977)

FIGURE I.

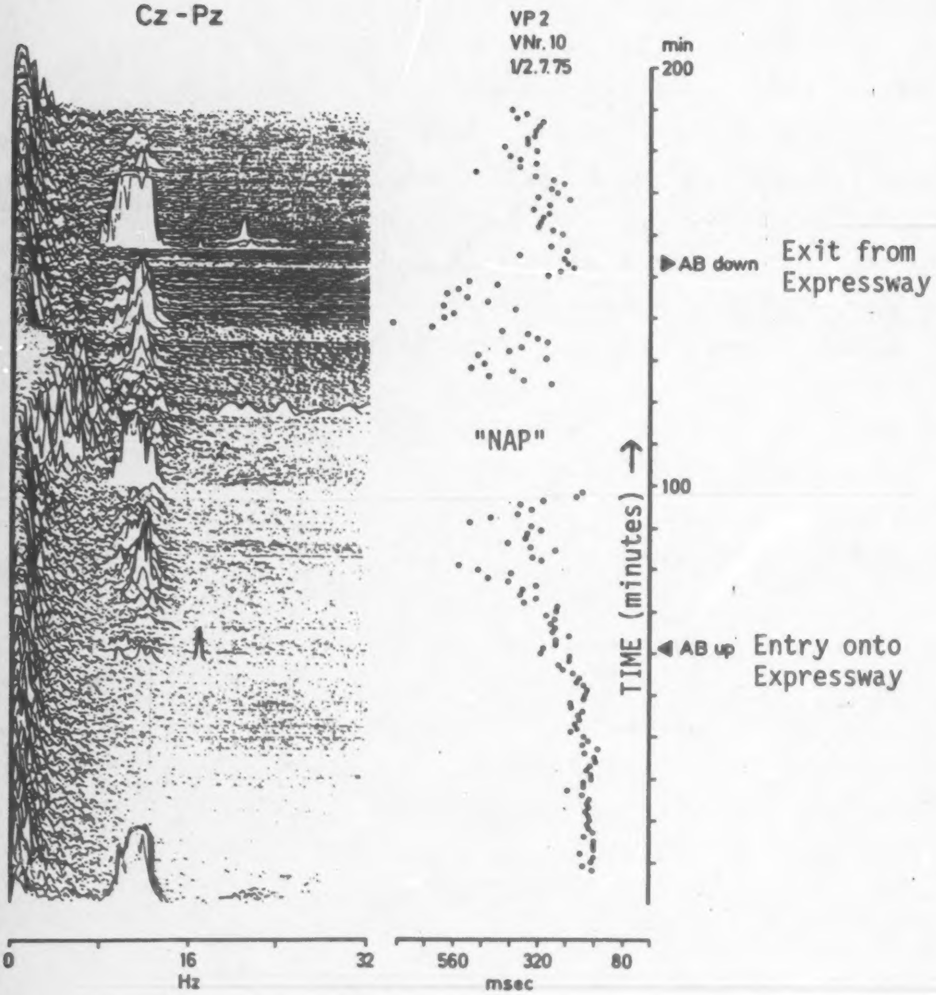


Percentage of accidents by time of day for dozing drivers and normalized percentage of trucks on the highway for a random sample of interstate drivers (exposure). (From H arris, 1977)

FIGURE II.

recording of brain waves and eye blink durations during experiments on night driving conducted in Germany (Figure III). Bursts of alpha activity in the electroencephalogram (normally associated with drowsiness) and long pauses between eye blinks occur frequently during a monotonous drive during the night on the German Autobon expressway. It is of particularly striking concern that the driver actually was napping by all EEG criteria from minutes 100 to minute 120 while driving the car on the expressway. Researchers in Sweden have documented that train drivers fall asleep by brain wave criteria on one out of every six night runs. Nonetheless, the train drivers continue throughout such "naps" to keep full pressure on the accelerator pedal, remaining unresponsive to red stop signals. I am sure that many in this room can recollect similar experiences of slowly drifting off the road onto the shoulder of an expressway before being startled awake by gravel under the tires. Unfortunately, circumstances--both on the highway and in the factory control room--are not always so forgiving.

High personnel turnover, high rates of accidents and illness, low morale and low productivity plague almost all shift work operations. No one would operate the machines which use electric power beyond their designed tolerances, for this would lead to excessive wear, frequent breakdowns and early replacement. Yet because we as human beings are not born with an instruction manual specifying our tolerances to disruptions in our work-rest schedule, it has been assumed if an individual is "tough", he or she should be able to "handle" almost any type of schedule. We must now begin to awaken to the fact that this simply is not so.



Comparison of EEG spectra and eye blink duration during a night driving experiment. Note the good correlation of the occurrence of alpha activity and long-duration eye blinks on the monotonous expressway. Nap between 100 and 120 minutes. The great alpha peak after leaving the expressway marks eye closure in front of red light. (From Fruhstorfer *et al.*, 1977)

FIGURE III.

What effect do such schedules have on the human body? At the present time, no one knows for sure what the long term health consequences of rotating shift work schedules are, although animal studies suggest that significant reductions in life span may be associated with weekly shift changes. The physiological impact in the short term, however, is quite apparent. When the demands of the work schedule exceed the capacity of the human organism to adapt, it causes two major daily timing systems or pacemakers in the body to uncouple or split apart. In this state of so-called "internal desynchronization," individuals are attempting to remain awake throughout the daily trough of the body temperature, alertness and performance cycles, when that system in the body is trying to put them to sleep. Those same individuals then try to sleep at a point in the cycle when that same system in the body is trying to wake them up -- when the internal alarm clock is going off.

Our results in the research laboratory have clarified why it is often so tough to sleep well in the morning after staying up all night. Most people wake up after only a few hours, despite the fact that they do not feel well rested. It turns out that sleep length, sleep quality and sleep efficiency all depend primarily on WHEN we sleep -- the time on our internal biological clock -- rather than on the length of prior wakefulness. Thus, shift workers often suffer from sleep loss, persistent fatigue and lack of alertness on the job, even after rotating onto the day shift. One of the most problematic facets of such chronic sleep deprivation is that the shift worker himself or herself often does not percieve the extent of the vigilence deficit, since this has gradually come to be established as "normal" after many years.

In addition to a high prevalence of sleep disorders, shift workers have a reportedly high number of digestive disorders such as gastric and peptic ulcers, gastritis and various intestinal disorders. There is now also evidence from Scandanavia for increased levels of cardiovascular risk factors among shift workers. Finally, shift tork is very disruptive to family life and social life, since the free time of shift workers is difficult to coordinate with that of family and friends. A number of these issues are reviewed in a chapter from the Institute of Medicine report entitled Health and Behavior, which is included as Appendix A to this testimony.

One might ask the question, "Why bother with shift work, for all of it's problems?" In fact, round-the-clock shift work operations have unfortunately become a necessary and important part of modern society. No one would accept police and fire protection only from 9:00 a.m. to 5:00 p.m. Operations as diverse as hospitals, hotels, airports, nuclear power plants and defense installations share at least one feature in common. They are not 9:00 a.m. to 5:00 p.m. operations. Many food, chemical and manufacturing processes inherently require continuous operation to avoid spoilage or to complete each "batch" of product. Furthermore, industries which require only a few people to operate very expensive equipment are economically forced to use that equipment around the clock. Thus, shift work in industrialized nations is growing steadily. Estimates from a National Institute of Occupational Safety and Health study in 1977 estimated that one quarter of the American work force currently does shift work. A more recent survey by the National Center of Health Statistics indicates that one out of four working men and one out of six working women has a variable work schedule, including both day shifts and night shifts. As indicated in Tables Ia and Ib, this is not predominantly limited to one specific age group or educational category but is instead surprisingly evenly distributed throughout the working population. While no one may

## TABLE Ia

### PROPORTION OF FULL-TIME CURRENTLY EMPLOYED MEN 20-64 YEARS OF AGE WITH A VARIABLE WORK SHIFT*

| Education | All ages 20-64 years | 20-34 years | 35-49 years | 50-64 years |
|---|---|---|---|---|
| All levels: | 26.9 | 27.2 | 28.4 | 23.9 |
| Less than 12 years | 28.0 | 29.7 | 30.1 | 23.9 |
| 12 years | 27.2 | 26.8 | 27.8 | 26.9 |
| More than 12 years | 26.4 | 26.8 | 28.1 | 21.5 |

*Percentage of affirmative responses to the question: "Does your job involve a variable work shift? That is, do you work the day shift some times and the night shift at other times?"

Source: National Center for Health Statistics Basic Data from Wave I of the National Survey of Personal Health Practices and Consequences: United States, 1979 (Schoenborn, C. A., ed.) Washington, D.C.: U.S. Government Printing Office, 1981, DHHS Publ. No. (PHS) 81-1163.

## TABLE Ib

### PROPORTION OF FULL-TIME CURRENTLY EMPLOYED WOMEN 20-64 YEARS OF AGE WITH A VARIABLE WORK SHIFT*

| Education | All ages 20-64 years | 20-34 years | 35-49 years | 50-64 years |
|---|---|---|---|---|
| All levels: | 15.5 | 17.3 | 14.9 | 11.7 |
| Less than 12 years | 22.4 | 20.0 | 25.4 | 22.1 |
| 12 years | 14.9 | 17.1 | 12.4 | 13.0 |
| More than 12 years | 13.9 | 16.9 | 13.8 | 3.7 |

*Percentage of affirmative responses to the question: "Does your job involve a variable work shift? That is, do you work the day shift some times and the night shift at other times?"

Source: National Center for Health Statistics Basic Data from Wave I of the National Survey of Personal Health Practices and Consequences: United States, 1979 (Schoenborn, C. A., ed.) Washington, D.C.: U.S. Government Printing Office, 1981, DHHS Publ. No. (PHS) 81-1163.

want to accept the need for scheduling work round-the-clock in our society, it is here to stay and we cannot continue to ignore this problem, thereby perpetuating the misuse of human energy and talent. We must begin to deal with the fact that this time, modern technology has really upset the apple cart. In the past hundred years, a mere instant on the evolutionary time scale, the temporal environment to which mankind as a species is exposed has been completely disrupted.

It is only within the past 20 years that much has been learned about the mechanisms by which our internal biological clocks interact with the external periodic environment. This work has begun to reveal what the limitations are in the capacity of the human organism to adjust to changes in the work-rest schedule. It's like trying to put together bits and pieces of that missing instruction manual. The discovery that the biological clocks of patients with certain types of sleep disorders could be reset, thereby ridding them of their insomnia, made me realize several years ago that it should be possible to design work schedules to which it would be easier for people to adapt, provided the people were also given the information necessary to take advantage of any changes which were introduced. The results of this biomedical research could then be put to their best advantage in a setting with far-ranging practical implications.

It was with these concepts in mind that Dr. Martin Moore-Ede, Dr. Richard Coleman and I decided in 1980 to form a non-profit service organization called the Center for Design of Industrial Schedules to facilitate the application of these basic research results to the workplace. Together, over the past several years, we designed and conducted the demonstration project at the Great Salt Lake Minerals and Chemicals Corporation in Ogden, Utah which was the impetus for these hearings.

Our report of the Great Salt Lake study was published in the July 30, 1982 issue of the journal Science, which is included as Appendix B to this testimony.

When Mr. Preston Richey, production manager at Great Salt Lake Minerals, first contacted me and described to me the work schedule with which they were operating, I realized that it flew in the face of everything which had been learned about how our biological clocks tick. An informal telephone poll of multiple facilities in a variety of industries than revealed to me that such a schedule was one of the most common schedules used in round-the-clock operations in the U.S., rotating workers every week to a new set of work hours.

In order to determine whether the concepts which we had developed in the laboratory would ring true in the workplace, we constructed a confidential survey questionnaire and administered it to all the hourly workers at Great Salt Lake Minerals. The results of this initial baseline survey are illustrated in Figure IV. Panel A indicates that the nearly 70% of the rotating shift workers had a moderate to severe problem with poor quality sleep. In fact, despite the fact that these workers were operating heavy equipment, nearly one-third of the workers admitted to falling asleep at work within the past 3 months(Panel B). Ninety percent of the rotating shift workers complained that the schedule changed too often (Panel C), which is understandable considering that 85% of the rotating shift workers reported that it took half a week or longer to adjust their sleep time following the weekly rotation (Panel D).

Based on that information, in applying circadian theory we decided to change the direction of shift rotation such that successive shifts

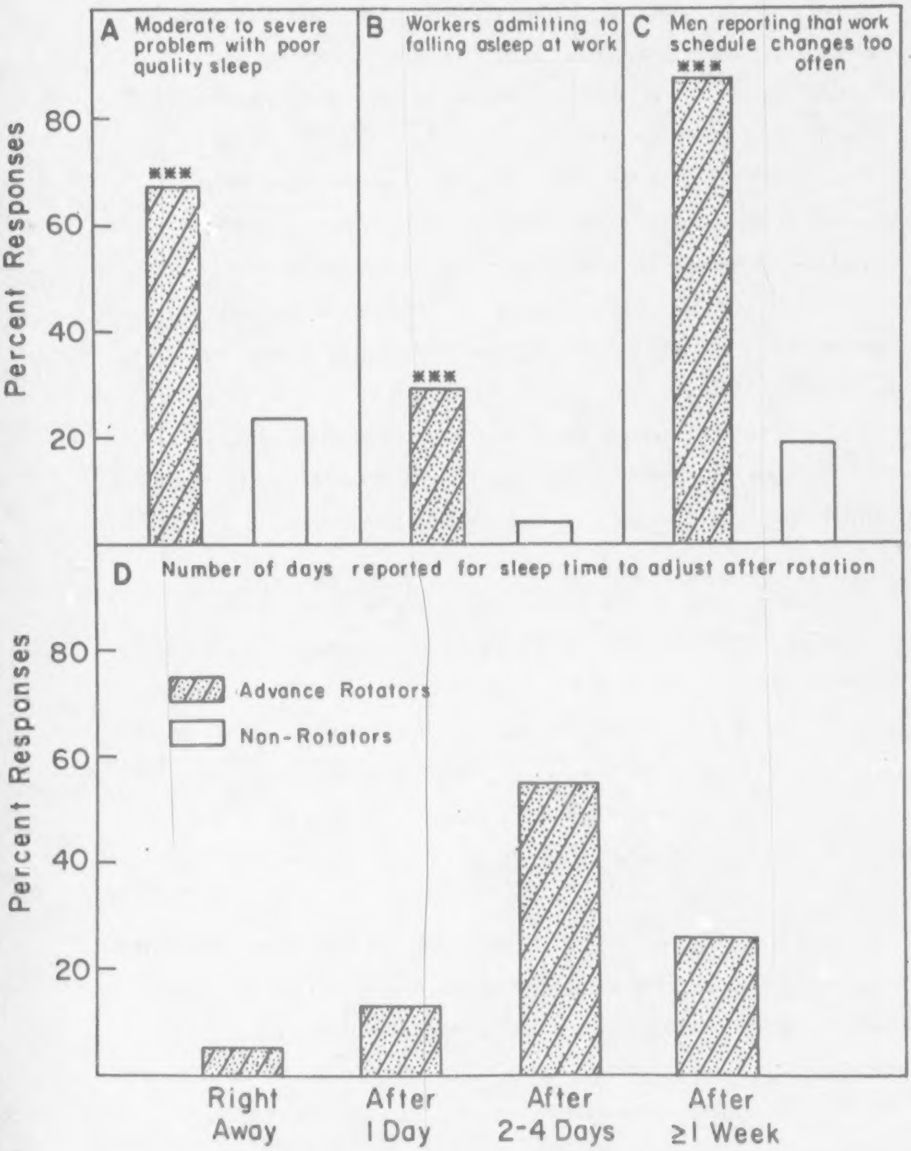


FIGURE IV.

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(A to C) Comparison of sleep-wake cycle questionnaire responses from workers on weekly phase advance rotating shifts and nonrotating day and swing shift workers. The rotating shift workers reported greater problems with (A), poor quality sleep, $\chi^2(1) = 26.4$, $P < .001$; (B), falling asleep at work, $\chi^2(1) = 15.6$, $P < .001$; and (C), the schedule changing too often, $\chi^2(1) = 55.0$, $P < .001$. (D) The number of days taken for the sleep time of the weekly phase advance rotating shift workers to adjust after each shift rotation. ***$P < .001$.

(From Czeisler, C.A., Moore-Ede, M.C. and Coleman, R.M., 1982)

Data gathered at the Great Salt Lake Minerals and Chemicals Corp.

should progress to later hours rather than advancing to earlier hours. Figure V shows that nearly three out of four workers preferred this new direction of shift rotation, as compared to their prior schedule. Figure VI shows a 27% improvement on a health index in the group which we predicted would fare best, on the basis of circadian theory. There was no appreciable change in the other groups, despite the fact that they were treated in an identical manner expept for the work schedule intervention. Finally, Figure VIII demonstrates the marked improvement in the performance of the workers following introduction of the new schedule. The rate of potash harvesting from the evaporation ponds rose 12% in the first quarter after its introduction, followed by a 22% rise in the second quarter and a 32% rise in the third quarter (compared with the same respective quarters over the prior two years).

The encouraging results of the Great Salt Lake study indicate that the application of circadian principles to the workplace can indeed be very productive, even at this preliminary stage in our understanding of the mechanisms which control the timing of the sleep-wake cycle. While the diversity of operational needs and specific requirements may limit the generality of the specific schedule introduced in the Utah study, the approach developed should be applicable in a wide variety of circumstances.

Certainly these results justify increasing our efforts to characterize the properties of the circadian timing system in man, as recommended in the Institute of Medicine report which is appended. Furthermore, in order to enable basic research to bear more relevance to the requirements of modern round-the-clock operations, it is critical that performance criteria be developed which are sensitive to the errors of inattention

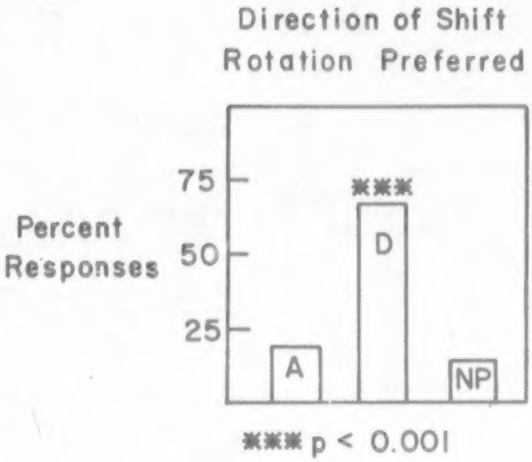

FIGURE V.

After experience with both schedules, workers preferred delay (D) rotating schedules over the advance (A) rotating schedule. NP= No Preference.

(From Czeisler, C.A., Moore-Ede, M.C. and Coleman, R.M., 1982)
Data gathered at the Great Salt Lake Minerals and Chemicals Corporation.

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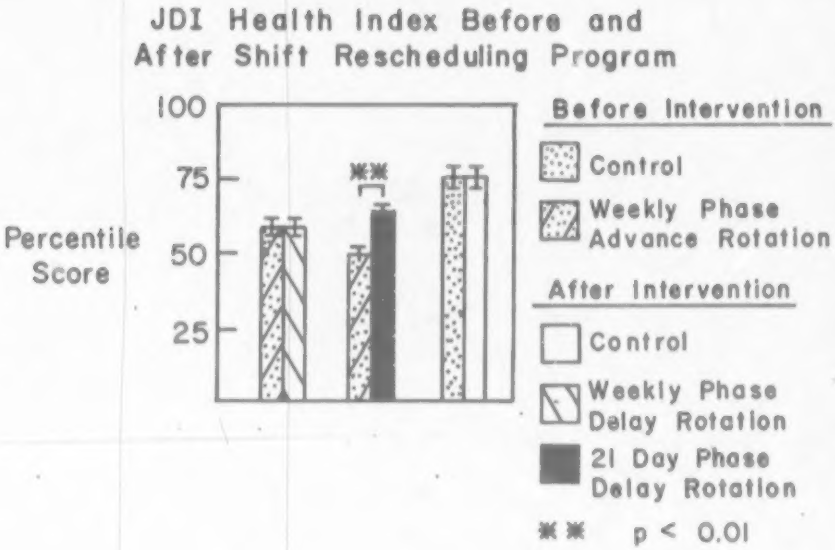

FIGURE VI.

Rotators on the 21-day phase delay schedule had significantly increased scores on the health index of Smith, Hendall and Hulin. No significant changes were seen in the other two groups before and after intervention.

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(From Czeisler, C.A., Moore-Ede, M.C., and Coleman, R.M., 1982)

Data gathered at the Great Salt Lake Minerals and Chemicals Corporation.

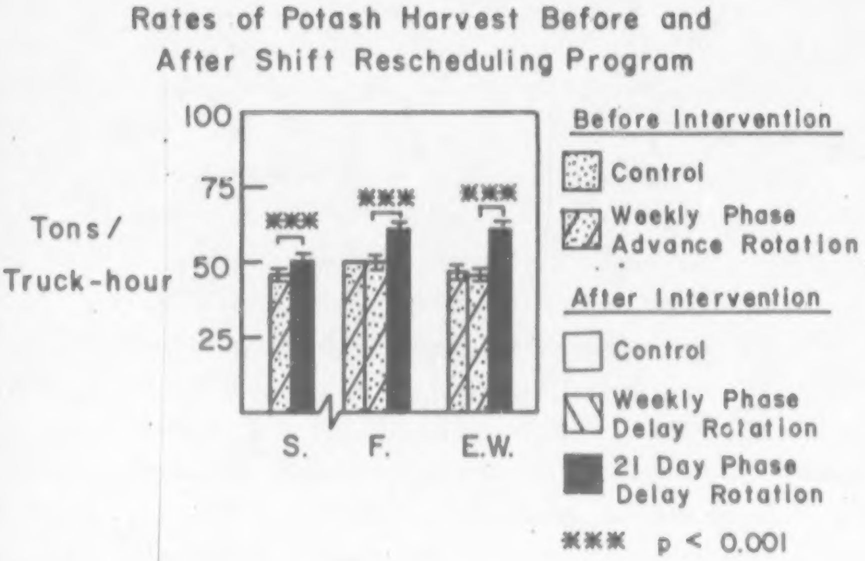

FIGURE VII.

Potash harvesting productivity increased significantly (Student's *t*-test) during the quarter season immediately following the introduction of the 21-day phase delay rotating schedule [$t(103) = 3.49$, $P < .001$] (left cluster); compared to the previous 2 years there were also increases in the first [$t(96) = 7.58$, $P < .001$] and second [$t(99) = 10.89$, $P < .001$] quarters after the summer break (middle and right clusters) (*11*, *12*)

(From Czeisler, C.A., Moore-Ede, M.C. and Coleman, R.M., 1982)

Data gathered at the Great Salt Lake Minerals and Chemicals Corporation.

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which are currently not detected by existing performance testing batteries. There must be a closer collaboration in research efforts between agencies such as the Nuclear Regulatory Commission or the Department of Defense and the physiologists undertaking this research. Reports prepared for the U.S. Nuclear Regulatory Commission and the Air Force Office of Scientific Research (attached in part as Appendix C and Appendix D) indicate that those agencies are acutely aware of the critical importance of such research efforts to the consistent success of the monitoring and surveillance activities which those agencies oversee. Yet perhaps because of a lack of direction, there are no systematic efforts being mounted to address this pressing need. The reports state, for example, that: "Loss of operator alertness ... must be viewed as one of the most consequential performance shaping factors in nuclear powerplant operations." (NUREG/CR-2833), or "Research is needed to provide the sleep-wake cycle information needed to design duty-rest cycles which least disrupt the sleep-wake cycle and minimize deteriorations in alertness and performance." (AFOSR, see Appendix D, p. 35). Yet, instead of stimulating action, these reports are collecting dust on library shelves.

I feel, Mr. Chairman and members of the Subcommittee, that the time has now come to seize this opportunity to address this pressing issue. This area of applied and basic research holds the promise of minimizing, for the 20-30 million shift workers in this country, the detrimental effects on health and performance of sleep-wake cycle disruption. It may thus make it possible to release more of the American workers' potential at a time when it is critically needed in an increasingly competitive world market. Thank you very much for having given me the opportunity to bring these issues to your attention.

# APPENDIX A.

From: Health and Behavior: A Report of the
Institute of Medicine,
U.S. National Academy of Sciences
National Academy Press,
Washington, D.C., 1982.

## 6

## Sleep, Biological Clocks, and Health

Sleep disturbance or insomnia is a widespread problem among adults. Between 29 and 39 percent of individuals over age 18 in the United States (or 45 to 60 million persons) perceive themselves as having had trouble sleeping within a given year (Institute of Medicine, 1979). Of these, 8 to 12 million seek help from a physician, and an estimated 4 to 6 million receive a prescription for sleeping pills. The Institute of Medicine report *Sleeping Pills, Insomnia, and Medical Practice* raised questions about this extensive use of drugs in the treatment of insomnia. There were 25.6 million prescriptions for sleep medications in 1977 alone, in addition to the estimated 30 million packages of over-the-counter sleep aids purchased annually. A survey of 4,500 physicians showed that when patients complain to a doctor about trouble with sleeping, about 55 percent are routinely given a prescription. Such practices would not have been continued over the years if patients did not often report benefit, but the scientific basis for this clinical judgment is modest.

The evidence for efficacy and safety of sleep drugs in long-term use is limited. There even is evidence suggesting that chronic use may exacerbate rather than ameliorate the difficulties of some insomniac patients. There are significant hazards associated with their use, including the dangerous interaction of such drugs with alcohol, their interference with daytime performance, rebound insomnia leading to habitual drug use, and the easy availability of such drugs for suicide. The costs to society may include increased mortality from their use in suicide or accidental overdose; costs of treatment for nonfatal overdose emergencies; morbidity, mortality, lost

productivity, and even increased crime because of addiction to some of these drugs; and potential safety hazards from persons operating machinery or driving while still under the influence of sleep medication (Institute of Medicine, 1979; Solomon et al., 1979).

Insomnia is not a unitary disorder, and there is a need for development of specific modes of treatment—both pharmacological and nonpharmacological—for different forms of insomnia. A paucity of existing knowledge currently prevents selection of one treatment approach over another, or even one drug over another, although several useful interventions are available. Further progress will depend heavily on basic research on the neurobiology and psychology of sleep. One area—biological rhythms—is examined here as a case study for basic, clinical, and epidemiological research.

### Sleep and Biological Rhythms

The relationship of sleep to biological rhythms is a promising area of basic research that may be fundamental to understanding and classifying some forms of insomnia. Recently, the Association of Sleep Disorders Centers (1979) has recognized in its classification of sleep and arousal disorders that "sleep scheduling disorders" are a distinct subtype of insomnia.

The daily cycle of sleep and wakefulness normally is synchronized to the periodic external environment by an internal biological clock. This physiological timing system shares the properties of similar circadian rhythms in a wide array of life forms, from single-cell algae to the entire plant and animal kingdom (Moore-Ede et al., 1982). In human beings, each day's sleep and wakefulness normally are consolidated into separate blocks, with sleep occurring at night and wakefulness occurring during the daytime.

Over the past decade, the merger of research findings from two disciplines—circadian physiology and sleep disorders medicine—has yielded greater understanding of the physiological and behavioral processes that affect the timing of the sleep-wake cycle and its relationship to the environmental day-night cycle. Acute phase shift experiments that put subjects to bed at an unaccustomed time of day have demonstrated that sleep disturbance results if sleep is shifted by 6 to 12 hours from the habitual time. The disturbance is characterized by awakening toward the end of sleep, together with an abnormal progression of sleep stages within the sleep time and an increased fragmentation of sleep patterns (Webb et al., 1971; Taub and Berger, 1973; Hume, 1978; Weitzman and Kripke, 1981). This confirms reports by shift workers and persons suffering from "jet-lag." Although most shift workers attribute disturbances in daytime sleep that follows nighttime work to daytime noise (Knauth and Rutenfranz, 1972a,b), sleep at that time of day would be disturbed even in the absence of noise.

Insight into the environmental factors that affect the timing of sleep has been achieved through studies of human beings living in schedule-free environments such as deep within caves, isolated from the periodic day-night changes of the environment, or in controlled laboratory settings designed to achieve the same results (Zulley et al., 1981). In such constant conditions, the timing of the sleep-wake cycle and of a variety of other physiologic functions continues to be periodic. Researchers have found that the length of unrestricted sleep varies with the phase of the self-sustained circadian rhythm of body temperature (Czeisler, 1978; Zulley, 1979; Czeisler et al., 1980). Furthermore, in a well-designed study simulating sleep after a night of shift work, Akerstedt and Gillberg (1981) verified the previously unexplained report of Foret and Lantin (1972) that major reductions occur in the duration of sleep of train drivers working at night and trying to sleep by day. They concluded that the primary determinant of the length of sleep was the phase of the body temperature cycle at bedtime rather than the length of prior wakefulness.

The results of this basic and applied research help explain why shift workers are only able to sleep a short time when they go to sleep at 8 to 10 a.m. They are trying to sleep at the "wake-up phase" of their internal biological clock. Not only is sleep cut short but the temporal organization of the sleep stages also is altered (Czeisler and Guilleminault, 1980).

## Treatment of Sleep Scheduling Disorders

The impact of *when* bedtime occurs on *whether* sleep can occur prompted Czeisler et al. (1981a) to apply the properties of basic research on biological clocks to the diagnosis and treatment of the Delayed Sleep Phase (DSP) type of insomnia, a sleep scheduling disorder. They noted that patients with DSP insomnia were able to sleep well, but only if they slept at the "wrong" time of day (e.g., 4 a.m. to noon). They hypothesized that DSP insomnia was due to a specific abnormality of the system that regulates the time of sleep, rather than to a dysfunction of the sleep-generating process itself. This led to the development of a successful nonpharmacological treatment for DSP insomnia that employs the best method effectively to reset the biological clock responsible for timing the occurrence of sleep. Such studies emphasize the importance of recognizing the impact of biological clocks on the timing of sleep and other processes.

## Properties of Biological Clocks

Human beings, like most other species on earth, have evolved in a regular 24-hour light-dark cycle. Although the earth's daily spin on its axis has been slowing down over the past one million years (Cosle, 1974), the day length when humanlike forms first appeared was only 20 seconds shorter than it is now (Rosenberg and Runcorn, 1975). In comparison, environmental changes of the last 100 years have been immense. With the invention of the light bulb and the airplane, superimposed on the industrial revolution, there have been unprecedented changes in the temporal environment to which humans are exposed. Only since the invention of artificial light sources have human beings attempted on a large scale to manipulate the timing of the sleep-wake cycle to accommodate socioeconomic needs.

Travel to the east or west used to be sufficiently slow so that the daily light-dark cycle rarely deviated by more than an hour—well within the capacity of the body to adjust. Today, however, millions of people are abruptly subjected to shifts in environmental time cues when they work on shift work schedules or fly across time zones. Still others are in settings such as a hospital intensive care ward, where they are largely isolated from daily time cues.

In the absence of periodic environmental time cues, the cycle length or the free-running period length of circadian rhythms is no longer synchronized or entrained to a 24-hour period. Whether the free-running period is greater or less than 24 hours depends on the species; nonetheless, it remains close to 24 hours in all species. In normal human subjects, the average free-running period of the sleep-wake cycle is approximately 25 hours. In other words, in constant conditions the internal biological clock runs a little slower than its mechanical or geophysical counterparts. Therefore, successful synchronization of human circadian rhythms (including that of the sleep-wake cycle) to the 24-hour day requires that the biological clock be "reset" by an average of one hour each day.

It is generally accepted that the most important periodic environmental stimulus for entraining circadian rhythms in nearly all species is the daily alternation of light and dark (Rusak and Zucker, 1975). However, the effectiveness of a light-dark cycle alone as the synchronizer of circadian rhythms in human beings has been shown only recently (Czeisler, 1978; Czeisler et al., 1981b). The relative importance of different synchronizers to the human system remains unknown. Still, it is clear that the combination of an imposed light-dark cycle with scheduling of the time available for sleep and waking is a very effective synchronizing cue for all measurable human circadian rhythms.

Nearly 10 years ago, a specific area of the brain—the suprachiasmatic nucleus (SCN) of the hypothalamus—was identified as a central neural pacemaker responsible for the generation of many overt circadian rhythms such as the rest-activity cycle and many neuroendocrine rhythms (Moore and Eichler, 1972; Stephan and Zucker, 1972). A newly discovered monosynaptic pathway from the retina to the hypothalamus, the so-called retinohypothalamic tract, enabled researchers to locate the SCN. The tract appears to be responsible for transmitting photic stimuli for synchronization of this neural system with the external light-dark cycle (Moore, 1974). The human circadian system is, however, a multioscillator system (Wever, 1979). Under certain conditions, it reliably splits into two separate groups of rhythms that appear to be driven by separate pacemakers. Lesioning of the SCN in primates results in the loss of rhythmicity in certain functions such as activity while rhythms in functions such as body temperature persist (Fuller et al., 1981). Recently, Kronauer et al. (1982) have developed a mathematical model of the human circadian timing system using two interacting sinusoidal oscillators. This model system has successfully explained a number of results of the interaction between the human circadian timing system and periodic environmental time cues. These results imply the existence of a second pacemaker within the human brain, although its location has yet to be identified.

## Voluntary Disruptions of the Sleep-Wake Cycle

In addition to patients who present with the primary complaint of insomnia due to an intrinsic disorder of the sleep timing process, many persons have had disruptions of the timing of their normal sleep-wake cycles by altered work or travel schedules.

### *Occupational Schedules (Shift Work)*

There has been a dramatic increase over the past 20 years in the prevalence of shift work throughout industrialized nations. Though it has always been an integral part of most military operations, recent increases in the civilian sector have been striking. In France, shift work rose from 10 percent to 22 percent between 1957 and 1974. In the United States, shift work in manufacturing centers has been increasing about 3 percent every five years; full-night-shift workers rose 13 percent over the last three-year period reported (Johnson et al., 1981). Some major industries have more than half their workers on shifts.

Shift work has developed to such an extent because of the demand in modern societies for use of expensive equipment around the clock; the need for continuous attention to technological processes in the chemical, steel, and energy industries; and the demand for 24-hour services from hospitals, transportation, and emergency services. Shift work schedules vary greatly; working shifts may be from 6 to 12 hours in length (Tasto and Colligan, 1977). When the sequence of shifts changes frequently, the shift worker is exposed to an average day length that is significantly different from 24 hours. An extreme example is the work pattern of the men in the U.S. Navy who operate nuclear submarines (Schaeffer et al., 1979), who typically work with 6 hours duty and 12 hours of rest—an 18-hour day-night cycle. The rationale from the Navy's viewpoint is that 8-hour duty spans are too long for peak vigilance to be maintained and there is only space on the submarine to carry three shifts of men. This solution ignores the fact that an 18-hour day-night cycle exceeds the range to which the human sleep-wake cycle can adapt.

Some schedules may have permanent assignment to a given shift, others may rotate rapidly (every one to two days) or slowly (every week or month) (Rutenfranz et al., 1977). Some have the crews rotating to earlier shift hours; others, to later ones. Even those who always work on the night shift may still be subject to changing environmental schedules if they adopt daytime activities for social reasons during weekends or vacation.

### *Transmeridian Travel (Jet-Lag)*

Since the 1950s and the advent of widespread commercial jet travel, increasing numbers of persons have been exposed to the effect of rapid movement across time zones. Most international air routes are in an east-west direction, rather than a north-south direction, because many of the major centers of international commerce are in Europe, the United States, and Japan—all located at similar latitudes. Airline flight crews are exposed to particularly irregular schedules; they are subjected to a combination of the effects of shift work and jet-lag (Institute of Medicine, 1981a).

## Health Consequences of Abnormal Work Schedules

Despite substantial increases both in the number of people exposed to abnormal temporal work-rest schedules and in the extent to which such schedules deviate from the regular 24-hour day, there has been relatively little effort to explore physiological, medical, economic, or psychosocial consequences of these major variations in work-sleep schedules. The rapid pace of the investigation and convergence of research findings in sleep, biological rhythms, and behavior recently led the National Institute of Occupational Health and Safety (NIOSH) to hold a symposium on the 24-hour workday entitled *Variations in Work-Sleep Schedules* (Johnson et al., 1981). This symposium brought together experts in sleep research, biological rhythm research, and occupational medicine.

### Long-Term Effects of Shift Work

There are significant differences in the tolerance that people have for working or sleeping on abnormal schedules (Reinberg et al., 1978, 1981). Differences may be related to properties of their circadian timing system such as the amplitude of the oscillation. When schedules entailing night work were first adopted by the armaments industry in World War I, an especially large number of stomach disorders occurred among night-shift workers (Vernon, 1921). In 1939, Duesberg and Weiss calculated that the risk of stomach ulcer was eight times greater for such workers than for those on day schedules. However, since World War II, comparisons of the health of shift workers with the general population have not been so striking. This is probably because a constant process of selection takes place among shift workers. Few now are forced onto night-shift schedules, although economic need may implicitly pressure people into accepting such work. Those who cannot cope with night-shift schedules often switch to another job. Thus, statistical comparisons between night workers and day workers are biased against finding any differences.

The long-term health consequences of abnormal work and sleep schedules in human beings are unknown. No long-term human studies have been conducted on the effects of extended exposure to night-shift work, with the cumulative sleep deprivation and disruption of the sleep-wake cycle that this entails. Animal studies document the need for research. For example, laboratory animals subjected to a 6-hour phase shift of the light-dark cycle every week (similar to a rotating shift work system) had a 20 percent shorter life span than did those kept on a normal 24-hour schedule (Aschoff et al., 1971). Naturally, these animals did not choose to participate in the shift routine, whereas workers do have a choice. Careful long-term follow-up studies of chronic shift workers are needed to see if there are similar long-term consequences to such altered routines in humans.

Abnormal sleep duration is reported to correlate with disease consequences, although the data are hard to interpret. In a large prospective study, Kripke et al. (1979) found that otherwise healthy individuals who initially reported that they habitually slept much less or more than average were more likely than controls to have died by the six-year follow-up. There are many potential explanations for this finding, including possible effects of long-term use of sleep medications; but all explanations imply a complex relationship between sleep habits and general health. As noted earlier, a major topic is the appropriate use and long-term effects of drugs for those who are unable to sleep.

A big problem in conducting epidemiological studies of shift work is in comparability of study samples. There is a surprisingly wide array of shift work schedules currently in use (Tasto and Colligan, 1977). Some of them, though classified as shift work, never involve night work. Furthermore, the U.S. Labor Department's Bureau of Labor Statistics monitors only the starting times of workers for the major U.S. industries (Colligan, 1981). Thus, little information currently is available on the number of people who rotate shifts; even the sketchy information that is available only describes workers in major industries, which may or may not correlate with practices elsewhere. The extent of the problem, however, is indicated by a recent interview survey that showed that 27 percent of employed men reported jobs involving work shifts, including both day and night shifts (National Center for Health Statistics, 1981).

Thus, the objective health status of shift workers and the long-term health consequences of shift work require investigation. The mortality and morbidity rates associated with exposure to shift work could be collected in relation to the differing categories of shift schedules worked. An international classification system of shift work schedules together with an international shift work registry could be established. The World Health Organization and the International Labor Organization might be enlisted to facilitate international cooperation.

At present, the best-documented health consequences of night-shift work are disorders of sleep and disorders of digestion (Rutenfranz et al., 1976). There also are reports of respiratory problems and lower back pain (Japan Association of Industrial Health, 1979; Kogi, 1981). However, the incidence of cardiovascular disease and neurological disorders among shift workers seems not to be greater than for the general population (Rutenfranz et al., 1977).

### Sleep Disorders

Night duty, whether scheduled on a permanent or rotating basis, results in the most disruption of the sleep-wake cycle. Foret and Lantin (1972) reported major reductions in the duration of sleep in train drivers working at night and trying to sleep during the day; the drivers had great difficulty sleeping past noon, regardless of when they went to bed. A survey of 1,200 factory workers in St. Louis reported a 15 to 20 percent decrease in the reported duration of sleep following night duty, with nearly half the workers having difficulty in falling or staying asleep (Tepas et al., 1978). Averaging results of 198 surveys of a total of 4,500 shift workers conducted over the past 25 years, about 62 percent of those working at night complained of sleep disturbance (Rutenfranz et al., 1981).

A retrospective study of 115 former shift workers indicated that 90 percent considered their sleep while working shifts to have been disturbed

(Aanonsen, 1964). This is markedly greater than the one third of the overall adult population who report some sleep disturbance within a given year (Institute of Medicine, 1979). It is unknown to what extent the 14 million shift workers in the United States contribute to the estimated 50 million adults who have trouble sleeping. Similarly, it is unclear to what extent imposed variations in sleep by work schedules, leisure activities, or social demands contribute to the 8 to 10 million people who annually bring their sleep complaints to the attention of a physician.

### *Disorders of Digestion*

Digestive problems associated with shift work include gastric and peptic ulcers, gastritis, and various intestinal disorders (Japan Association of Industrial Health, 1979; Kogi, 1981). Again, worker self-selection appears to play a major role in studies of the relation of digestive disorders to shift work. A study of 128 shift workers found they had a two- to fourfold increased incidence of gastrointestinal disorders such as peptic ulcers when compared with a general population of workers who had never been on shift work (Aanonsen, 1959, 1964). About 10 to 20 percent of workers who began shift work reacted to shift work with gastrointestinal diseases. Hence, shift work may only be well tolerated by a segment of the population. Although more than half of shift workers surveyed in various studies complained of disrupted eating habits and 20 to 40 percent complained of gastrointestinal disturbances (Rutenfranz et al., 1981), results of studies of gastric ulcer disease in shift workers have varied from an eightfold increase over day workers (Duesberg and Weiss, 1939) to an equal ulcer incidence (Aanonsen, 1959, 1964). These findings led the NIOSH symposium to recommend a concerted international effort to establish an international classification system for shift work schedules, together with national shift work registries in each of the major industrialized countries based on that classification scheme.

### *Other Potential Hazards*

There are also potential dangers associated with shift work due to the hazards of operating complex equipment, monitoring safety indicators, or making important decisions while operating on a disrupted routine. This is particularly true as the demands of continuous industrial processes have required the performance of complex cognitive tasks at all hours (Wojtczak-Jaroszowa, 1977). Few data are available from field studies, but laboratory studies indicate significant time-of-day effects in performance measures (Folkard, 1981). Field studies that have been done indicate that the incidence of errors at work is much higher in the early morning hours (3 to 5 a.m.) than at any other time of day by people who have not fully synchronized to the new schedule—and most shift workers on rapidly changing schedules do not become synchronized. The delay before telephone calls are answered (Browne, 1949), the errors in reading meters (Bjerner et al., 1955), and the number of errors in answering warning signals (Hildebrandt et al., 1974) all increase during the early morning hours. Similarly, truck drivers have an extraordinarily elevated risk of having single-vehicle accidents at 5 a.m., compared with other times (Harris, 1977).

Human errors by pilots or air traffic controllers contribute to aircraft accidents. To what extent does this reflect incomplete adjustment to their shift work schedule? The exact contribution of their disrupted duty-rest schedule is hard to ascertain, because the extensive accident reports that the National Transportation Safety Board prepares after an aircraft accident do not evaluate the prior work-rest schedule of the crew or air traffic controllers involved (Moore-Ede and Fuller, 1980).

It is of interest to note that the nuclear power plant accident at Three Mile Island in 1979 occurred at 4 a.m.—in the middle of the night shift of 11 p.m. to 7 a.m.—with a crew that had been on night duty for only a few days and had been rotating on a weekly basis around the clock for the previous six weeks. Ehret (1981) has pointed out how the nuclear power plant operator is confronted by a complex array of instruments and instrument panels in a monotonous environment. A decrease of vigilance or performance of psychomotor tasks such as reading meters (Bjerner, et al., 1955) and responding to emergency calls (Hildebrandt et al., 1974) could contribute to a sequence of events that precipitates accidents.

### *Psychological Stress*

Shift workers report serious disruptions of social life because their free time is not coordinated with that of family and friends. This causes stresses in family life (Japan Association of Industrial Health, 1979; Kogi, 1981), especially because of conflicting demands on the shift workers who may want to sleep during the daytime, when their spouses and children are awake and making noise.

The commonplace experience of sleep disturbances following acute stressors has been confirmed experimentally (Lester et al., 1967; Goodyear, 1973). In addition, Healey (1976) found that, compared with controls, chronic insomniacs reported significantly more stressful life events during the year in which insomnia began, suggesting that acute stressors may allow wakefulness to intrude into sleep and might induce long-term sleep disturbances. On the other hand, sleep may have a protective role in certain stressful situations. For example, Cohen (1975) noted that subjects who underwent mildly threatening experiences before bedtime had increased amounts of rapid-eye-movement (REM) sleep and suggested that sleep might provide a psychological defense. Aakvaag et al. (1978) showed that even short periods of sleep during a five-day military exercise could reverse stress-related changes in growth hormone, prolactin, and testosterone. Perhaps altered sleep is a physiological response to physical or psychological stressors that lead to actual sleep disturbances only under certain extreme conditions (Institute of Medicine, 1981b; Elliott and Eisdorfer, 1982).

Sleep deprivation is psychologically and physiologically stressful. Prolonged sleep deprivation can produce marked decrements in performance, coordination, motivation, and concentration. Yet in psychiatric patients it can have activating effects. Mendelson et al. (1977) reported that one third to one half of severely depressed patients showed a transitory antidepressant response after a full night of sleep deprivation. An increased appreciation for the importance of biological rhythms has encouraged a reexamination of the effects of sleep deprivation, because of its impact on the circadian timing system. For example, Taub and Berger (1976) described performance deficits in normal subjects whose sleep was displaced forward or backward by three hours, even though their total sleep time was essentially unchanged. Furthermore, Wehr et al. (1979) have shown that shifting the sleep-wake cycle by six hours to earlier clock hours (a phase advance) can act as an antidepressant. This may be one route by which sleep deprivation achieves its previously noted antidepressant effect (Mendelson et al., 1977).

## Conclusions

The disruption of mealtimes and rest periods is the most obvious putative cause of the gastrointestinal and sleep disorders associated with disrupted work-rest schedules. Food is provided at times of day when the endogenous circadian rhythmicity of the gastrointestinal tract does not anticipate it (Suda and Saito, 1979). Similarly, shift workers often cannot sleep when their circadian system would normally precipitate it and instead try to sleep near the maximum of their endogenous rhythm of alertness. Hence, they fail to obtain needed rest. Also, they are trying to function at maximum capacity when their physiological systems are geared down to minimum levels of alertness and cognitive functioning.

With frequently changing shifts, the body is in a constant state of forced internal desynchronization. The cycles in the environment such as light-dark, social cues, and food availability, which normally synchronize the circadian system, are disrupted and may even provide conflicting phase information. Hence, predictability of internal physiological events is constantly disrupted. Studies in primates have demonstrated failures of homeostatic mechanisms when periodic environmental time cues are disrupted (Fuller et al., 1978). It would not be surprising if there were long-term health consequences from living on disrupted schedules. The main task ahead is to determine more precisely the costs of such practices, so that they can be weighed against the benefits. At the same time, a concerted effort must be made to determine the best way to minimize disruptions to the human physiological timing system caused by needed round-the-clock duty scheduling.

Given the multidisciplinary nature of the problem, a broadly based approach to research would be most helpful. The types needed would include investigations into:

- basic neuroanatomy, neurophysiology, and neuropharmacology both of the sleep-wake cycle and of the circadian timing system in human beings;
- temporal organization of the circadian timing system, including the behavioral physiology and neuroendocrinology, with mathematical modeling of the system;
- basic physiology of sleep and wakefulness and their synchronization by the environment;
- medical and psychological effects of altered environments;
- optimal design of shift work schedules to minimize disruption of the circadian sleep-wake cycle and other timing systems;
- development of an international classification system for shift work schedules; and
- studies of workers entering shift work, with special emphasis on the interaction of different shift schedules with other hazards and protective factors in the work place, as probed by prospective epidemiological methods.

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APPENDIX B.

30 July 1982, Volume 217, Number 4558 **SCIENCE**

# Reports

## Rotating Shift Work Schedules That Disrupt Sleep Are Improved by Applying Circadian Principles

**Abstract.** *Workers on rotating shifts dislike those aspects of their work schedules that violate circadian sleep-wake cycle physiology. Work schedule satisfaction, subjective health estimates, personnel turnover, and worker productivity improve when schedules are introduced that are designed to incorporate circadian principles.*

The human sleep-wake cycle has evolved on a rotating planet with a regular 24-hour alternation between day and night. Yet within the past 50 years, the need for round-the-clock operations in many industrial plants and emergency services has led to major changes in the day-night schedules to which 26.8 percent of the U.S. work force is exposed, many of whom work shifts which rotate between night, evening, and daytime duties (*1*).

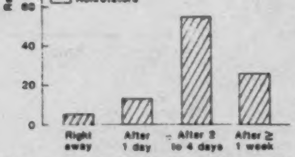

Fig. 1. (A to C) Comparison of sleep-wake cycle questionnaire responses from workers on weekly phase advance rotating shifts and nonrotating day and swing shift workers. The rotating shift workers reported greater problems with (A), poor quality sleep, $\chi^2(1) = 26.4$, $P < .001$; (B), falling asleep at work, $\chi^2(1) = 15.6$, $P < .001$; and (C), the schedule changing too often, $\chi^2(1) = 55.0$, $P < .001$. (D) The number of days taken for the sleep time of the weekly phase advance rotating shift workers to adjust after each shift rotation. ***$P < .001$.

Numerous medical and psychosocial problems associated with rotating shift work schedules have been reported (*2*), and several different approaches to the problems have been suggested (*3*, *4*). Because research findings (*5*–*7*) indicated to us that most rotating work schedules are outside the range of entrainment of the pacemaker timing the human circadian sleep-wake cycle, we postulated that a practical and effective intervention would be to resolve this aspect of the shift work problem. We report that rotating shift workers are often dissatisfied with the features of their schedules that violate circadian principles, and that when schedules are introduced which take into account the properties of the human circadian system, subjective estimates of work schedule satisfaction and health improve, personnel turnover decreases, and worker productivity increases.

We compared 85 male rotating shift workers, aged 19 to 68 (mean ± standard deviation, 31.4 ± 10.0), with a control group of 68 male nonrotating day and swing shift workers with comparable jobs, aged 19 to 56 (mean, 27.3 ± 8.2), at the Great Salt Lake Minerals and Chemicals Corporation in Ogden, Utah (*8*). For 10 years at this plant, weekly shifts were rotated with each crew working a given 8-hour shift for 7 days before rotating to the preceding 8-hour shift. Hence the scheduled work time rotated in a phase advancing direction from night (midnight to 8 a.m.) to swing (4 p.m. to midnight) to day (8 a.m. to 4 p.m.) shift (*9*).

Each worker was given the job descriptive and health indices of Smith, Kendall, and Hulin (*10*), and sleep-wake and schedule preference questionnaires. The response rate was 84 percent (*11*). The rotators reported significantly more [$\chi^2(1) = 26.4$, $P < .001$] problems with insomnia than did nonrotators (Fig. 1A) and 29 percent of the rotators reported that they had fallen asleep at work at least once during the previous 3 months (Fig. 1B). A major complaint was that the schedule changed too often (Fig. 1C), and 81 percent reported that it took 2 to 4 days or more for their sleep schedule to adjust after each phase advance; this included 26 percent who said they were never able to adjust before being rotated again (Fig. 1D).

To design a rotating work schedule that would take into account the properties of the circadian timing system, we focused on two key issues: the direction of rotation and the interval between phase shifts. In normal human subjects the endogenous free-running period of the sleep-wake cycle averages 25 hours, but that cycle can usually be entrained by periodic environmental time cues which are within 1 to 2 hours of the endogenous period (*6*). Thus the typical range of entrainment in man easily accommodates normal synchronization to the 24-hour period of the earth's rotation. This range allows in any one cycle only a small phase advance with respect to environmental time but a 2- to 3-hour phase delay (*12*). This explains why adaptation is more rapid after westbound travel (requiring a phase delay) than after eastbound travel (requiring a phase advance) (*13*). These considerations led us to conclude that work schedules that rotate should do so by successive phase delays and that the interval between phase shifts should be as great as is practical.

To test this hypothesis, we divided shift workers on phase advancing work schedules into two groups and placed them on phase delay schedules: 33 workers continued to change shifts each week and 52 others rotated shifts by phase delay once every 21 days (*14*). Before implementation of the schedule, all workers and managers attended an audiovisual presentation on the basic properties of the circadian sleep-wake cycle that had suggestions for adjusting their sleep time to their schedule, and each received an educational booklet designed for the workers at this facility.

The workers' preferences were evaluated from questionnaires distributed 3 months after the introduction of the new schedules (Fig. 2, A to D), and personnel

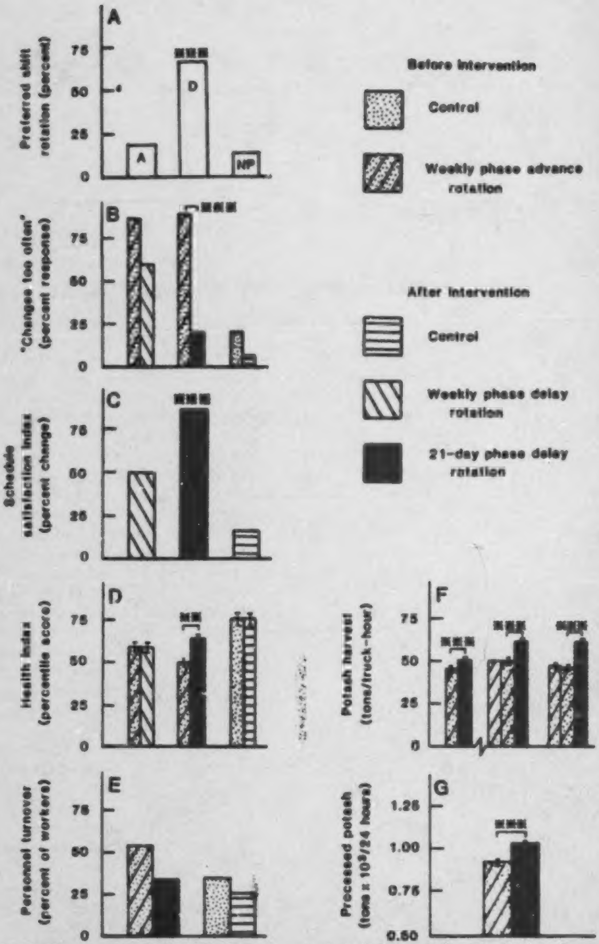

Fig. 2. Measures of worker satisfaction and productivity before and after introduction of new shift work schedules. (A) After experience with both schedules, workers preferred delay (*D*) rotating schedules over the advance (*A*) rotating schedule [$\chi^2(2) = 43.6$, $P < .001$]; *NP*, no preference. (B) There was a significant reduction [$\chi^2(1) = 47.8$, $P < .001$] in the complaint that the schedule "changes too often" by rotators on the 21-day phase delay schedule but not by rotators on the weekly phase delay schedule or by controls. (C and D) Rotators on the 21-day phase delay schedule had significantly increased scores on both the schedule satisfaction index and on the health index [$t(51) = 4.86$, $P < .001$, and $t(51) = 3.23$, $P < .01$, respectively]. (E) Personnel turnover rate during the 9-month study period among rotating shift workers (left) was reduced (after the 21-day phase delay schedule was introduced) to the same range as a comparable control group of nonrotating shift workers (right). (F) Potash harvesting productivity increased significantly (Student's *t*-test) during the quarter season immediately following the introduction of the 21-day phase delay rotating schedule [$t(103) = 3.49$, $P < .001$] (left cluster); compared to the previous 2 years there were also increases in the first [$t(96) = 7.58$, $P < .001$] and second [$t(99) = 10.89$, $P < .001$] quarters after the summer break (middle and right clusters) (*11*, *12*). (G) The production of processed potash increased significantly [$t(398) = 6.99$, $P < .001$] after introduction of the 21-day phase delay rotation schedule in comparison with the same period the previous year when the workers were on the weekly phase advance schedule. $^{**}P < .01$; $^{***}P < .001$.

turnover and plant productivity were analyzed 9 months after the introduction of the new schedules (Fig. 2, E to G) (*15*). The workers clearly preferred the phase delay direction of rotation (Fig. 2A); complaints that the schedule changed too often dropped from 90 to 20 percent among the workers on the 21-day phase delay rotation schedule (Fig. 2B). This was associated with a substantial increase on the schedule satisfaction index (Fig. 2C), improvements in the health index (Fig. 2D), and a reduction in personnel turnover (Fig. 2E) (*16*). At the same time, the rate of potash harvesting (Fig. 2F) by men operating front-end loaders in the evaporation ponds and the rate of processed potash production in the plant (Fig. 2G) also increased after the introduction of the new schedule, and the increases in productivity were maintained in the harvest season which followed the completion of our study period (*17*, *18*).

Previously three major strategies have been used to address the problems of adaptation to shift work. The first, and perhaps most obvious, is to schedule workers on straight shifts without rotation. However, it is often difficult to staff the night shift, and straight shift scheduling still results in conflicting environmental synchronizers for the night worker who adopts daytime activities for social reasons on days off. The second strategy, favored in Europe, is to rotate from one shift to the next rapidly in order to escape the consequences of partial temporal adaptation (*3*). However, the circadian system may be affected, even on rapid rotation regimens, since a change from the phase advance to the phase delay direction of a rapid rotation system resulted in some improvements in both psychological and physiological measures (*19*). A third strategy would be to take advantage of differences between individuals in measurable properties of the circadian timing system, such as rhythm amplitude (*4*), to select individuals with the greatest tolerance for working or sleeping on abnormal schedules.

In contrast, our strategy was to take advantage of those properties of the circadian system that individuals share in common: the longer than 24-hour endogenous period and the limited range of entrainment. The results of this field study indicate that work schedules that rotate by phase delay with an extended interval between each rotation are most compatible with the properties of the human circadian timing system. However, the design of any specific work schedule must, of course, take into consideration both the nature of the work and the specific needs of the workers.

The improvements recorded on the 21-day phase delay schedule are consistent with the results of temporal isolation and clinical studies (*5*, *6*, *12*, *20*). Mills *et al.* (*20*) showed that the circadian rhythms of volunteers usually show a phase delay of 16 hours in response to an 8-hour phase advance shift of schedule because such an abrupt phase advance is beyond the usual human range of entrainment (*6*). Most workers on phase advancing schedules may therefore be in a state of continual forced internal desynchronization (*13*, *21*) between the pacemakers (*7*, *22*) of their circadian system.

The consequences of such disruption in temporal organization are just beginning to be understood. It was only recently recognized, for example, that the normal timing and organization of sleep depend on an appropriate phase relation between circadian pacemakers (*5*, *23*). The forced disruption of phase relations inherent in shift work schedules accounts for the previously unexplained sleep disturbances reported in earlier field studies (*24*). Failures in homeostatic regulatory mechanisms are also associated with internal desynchronization of the circadian system (*25*), and chronic external desynchronization induced by light-dark phase shifts results in decreases of 5 to 20 percent in longevity in insects (*26*) and in mammals (*27*). In humans, the long-term effects of such phase shifts are not known, but field studies indicate that there are more sleep and digestive disorders among workers on rotating shifts (*2*), with some unable to tolerate the schedules (*28*). Concern about the possible long-term health consequences of rotating shifts is growing (*29*). It may be that the application of circadian principles to the design of schedules can maintain the temporal integrity of the circadian system and minimize for the shift worker any detrimental consequences of circadian disruption.

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14. The 21-day phase delay schedule was originally designed so that work hours were shifted gradually by 1 to 2 hours per day for 5 days until the new shift time was attained. This procedure was eliminated after a month when it proved inconvenient for the workers' family life and car pooling arrangements; thereafter an 8-hour phase delay was undertaken on every 21st day.
15. Rotating shift schedules for these workers generally operated during the potash harvest season from September through May. During the summer, most workers work straight day shifts.
16. That these effects are due to increased tolerance of the circadian system to the work schedule is supported by the fact that there was little improvement in other factors, such as indices of interference with family or social life.
17. It is unlikely that these increases in productivity reflected the presence of the study team since (i) productivity statistics were derived by retrospective analysis of company data that was routinely gathered; (ii) hourly pay scales were not linked to individual or group productivity; and (iii) the increases in productivity persisted throughout a 6-month follow-up after departure of the study team [H. M. Parsons, *Science* 183, 922 (1974)].
18. A time and motion analysis by a company operations engineer revealed that the modification and replacement of one of the harvesting machines during the summer of 1981 may have contributed up to 4 percent of the increase in productivity in the first and second quarters after the summer break (Fig. 2F, middle and right clusters), but this could not explain the increase in the quarter before the summer break

(Fig. 2F, left cluster), nor for more than a fraction of the increases in the subsequent quarters.

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## APPENDIX C.

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# Final Report On Biotechnology Research Requirements For Aeronautical Systems Through The Year 2000

Volume I

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July 30, 1982

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*This document is approved for public release;
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# Executive Summary

It is a truism that aircraft and their use in the military are evolving rapidly, whereas the pilots and crew are evolving hardly at all. Another truism, although frequently disregarded, is that the pilot is an essential element in any manned weapons system; his performance and protection must be accounted for during initial design, and not as an afterthought.

Looking to the year 2000 and beyond, we can expect aircraft that fly higher and faster, withstand higher G-loads and maneuver rapidly in all axes, remain aloft longer and serve as semi-autonomous command centers, and fly close to the ground and in high turbulence. Furthermore, they will be subjected to new threats from chemical, biological and radiation weapons. The principal role of the pilot will change to one of decision-maker and systems manager of a complex man-computer partnership. It would be a tragic mistake to wait until such vehicles were made operational before attacking those biotechnology problems that are potentially the Achilles heel of such advanced systems. A long-range program of basic and applied research in biotechnology should be aimed at identifying the potential problems and suggesting and validating candidate solutions. Having identified the problem areas, research can be directed toward identification of human limitations in the projected operational environment, the selection and training to optimize performance, the design of man-machine interfaces to achieve reliability and flexibility, and development of protective measures to enable the crew as well as the aircraft to survive.

In order to identify the major problem areas and plot basic research strategy, a Biotechnology Study Group was formed. The organization included an Engineering Technology Panel to define and advise on mission scenarios, and six Biotechnology Panels to define specific research topics to meet the needs associated with these missions. The following report contains abbreviated versions of the extensive research strategy recommendations made by the panels following a one-week study session in San Antonio during January 1982. A complete proceeding of this study session is published as Volume 2 of this report.

The role of the pilot in the future mission scenarios considered in this report differs substantially from his current role, to wit: information processing and decision-making, mission stresses associated with duration and acceleration, and protection against CBR threats. Whereas the latter two categories are extensions into newer domains of problems that are currently recognized, the first area represents a dramatic new departure. Automation in the cockpit is a reality, but the ways to use automation are by no means understood. Research programs are outlined for man-computer symbiosis, including new initiatives for two-way communication with machines and use of computer-aided decision-making in the cockpit. The management of several sources of information and its relationship to pilot workload is an area requiring extensive research. Research initiatives in non-conventional control modalities, including further use of voice commands, electromyogram and evoked-response controls, are suggested.

Enhancement of performance in unfriendly environments through the use of robotic systems and extension of stand-off weapons systems requires considerable research in terms of the human interface.

Research strategies are outlined to deal with the pervasive issue of monitoring and modeling of human performance under stress. Performance measures and models in the past, reflecting older technology, concentrated on the human as an element in a continuous control loop, whereas the emphasis for performance of the pilot in the year 2000 must be increasingly on his role as a systems manager. Modeling of the effects of environmental stressors on human performance, and especially the interactions associated with multiple stressors, represents a prime area for basic research in biotechnology. Problems of spatial disorientation and motion sickness will become more serious unless new approaches to training, aircraft design or pilot protection are achieved. Pilot protection from the stresses of unforgiving missions should take several avenues, including pharmacological approaches, research on high-G and vibration protection to reduce physiological reactions and biodynamic coupling, and early development work on a new generation of suits, helmets and escape systems. Research toward the approach of pilot protection and from the aerospace environment as an integrated systems problem, rather than a series of additional patches to the suit or helmet in response to each threat, is recommended.

The nature of missions envisioned by the year 2000 and beyond, as well as the cost associated with training in the air, indicate a substantial increase in the use of full or part task-trainers and simulation in pilot training. Major research initiatives are required to improve our understanding of flight simulator requirements and their effectiveness. In particular, the area of motion cues, their necessity and the ways of maximizing their utility need additional research. Visual augmentation through innovative use of external scene generation is another promising area for research in which the technology that currently exists is well ahead of our knowledge about how it should be applied. A closely related area associated with training is one of crew selection and enhancement. The frequently discussed notion of multiple track selection of Air Force pilots should be explored through a full-fledged training research program, since potential benefits are significant. In conjunction, we must improve our means of pilot evaluation and feedback of these evaluations at various stages of training to validate training effectiveness and the appropriateness of pilot selection criteria.

Consistent with the changing pilot role, selection criteria should be expanded to take into account appropriate measures of cognitive styles, an area where considerable research would be required before results could be implemented. Among a number of open issues in crew selection, attention is called to the need for research concerning individual variations in circadian rhythm patterns and their relationship to long or changing duty cycles. Crew enhancement research should be directed at sensory enhancement, especially visual, and the associated development of visual performance measurements more relevent to the aviation environment than those currently employed. Additional research is called for on topics related to crew fatigue and techniques for improving performance during long duty hours, including evaluation of relaxation and alerting techniques. Human factors research is required in the area of control and displays, with the possibilities of individualizing them to meet the needs and capabilities of each crew member.

Biological warfare protection will require substantial research in dealing with new biological agents and with the potential impact of genetic engineering approaches. The development of animal models for predicting central nervous system decrements associated with biological or chemical warfare threats is a continuing need, and such models will serve an important role in the evaluation of drug or other prophylaxis or treatment methods and their side effects. The links between physiological responses and behavioral measurements concomitant to CW and BW represents an essential area of basic research. New detectors and field techniques for identification of chemical warfare elements are required. Protection against CW as well as BW can be usefully studied in several new areas, including alternatives to current suits such as a disposable "protective skin" or advanced decontamination techniques. Protection against radiation threats will require research initiatives in two areas. The increasing concern with protection against laser weapons or inadvertent exposure to lasers requires not only continued study of eye protective devices but more basic research on the medical and performance consequences of laser damage to the eyes. A final line of new research concerns protection against pulsed radio frequence radiation. Models are required to understand the phenomenon at the molecular, cellular and tissue levels.

# 6

# Crew Selection and Enhancement

Current USAF techniques for selection of pilots are based on traditional psychological tests, psychomotor performance tests, physical standards arising from conventional examination techniques and a semistructured interview to determine motivation. All are applied to a volunteer population. Graduation from college is used as a performance standard.

This process yields a pool of flight training selectees, of whom some 20 percent will not complete flight training. Thus, flight training itself is a selection process, albeit lengthy and rather expensive. (The USAF has about $15,000 invested in a student pilot who washes out at the point of first solo flight.) The trend toward fewer and more complex aircraft makes it desirable to be more selective in identifying superior flying potential in applicants.

Since mission roles will become more and more complex and diverse, the "universally" assignable aircrew member will no longer be possible. While there will be a "minimum set" of standards required for military service, special selection standards will be required for each major aircrew mission role such as tanker, transport, bomber, fighter, RPV controller, weapon systems operators, information processors, etc. Selection standards and training will be closely coupled to mission demands. While there will be a shift in emphasis on the type of mission roles required (from physical/mechanical to information assimilation, integration, decision making, and execution), a wide range of mission roles (including the traditional aircrew roles presently used) will still be needed by 2000.

## Selection Criteria Development

The first criterion of selection is that candidates be capable of the physical performance demands of flying. Research is needed to develop instrumentation for monitoring the physiological performance variables in simulators and in flight. Similarly, instrumentation must be developed that can accurately simulate the physical requirements of the crew members under various mission conditions. Further research will be required to establish performance criteria and standards, based on these measures, for each of the crew positions of operational aircraft. Much of the data for these efforts should be obtained during actual flight and should include muscular strength, work, power, endurance, and sustained analytic mental capacity required to perform the various missions' tasks. A laboratory flight simulator will also serve for acquiring data for this purpose.

The motivation of volunteers for flight training requires evaluation to ensure that their motivation is not flawed or misdirected. At present, only the most superficial screening is performed, and there is no feedback to interviewers to allow them to determine if they are picking "winners". Research studies are required of successful and unsuccessful students, highly rated pilots and those who develop a fear of flying to identify the psychogenic features of motivation to fly. These studies should define developmental and historical markers of success that can be used by less skilled evaluators.

The tolerance of a candidate to circadian disturbances or "jet lag" requires research. Transmeridian flight, which induces phase shifts between the circadian rhythms of the body and the timing of external environmental synchronizers, often results in non-specific fatigue, insomnia and sleep disturbances, gastrointestinal complaints, headaches, disorientation and irritability. Research is needed to identify individual parameters of the circadian system. It should be determined if these predictive factors, when obtained from simulations, can be extrapolated to predict readaptation and to evaluate possible carry-over influence when duty schedules are frequently changed. This circadian system research should define the mechanisms of circadian phase resetting and the environmental parameters that influence resynchronization. The neurophysiological mechanisms involved must also be established. Based on this understanding, efforts should be made to develop phase resetting drugs and to develop mathematical models of the human circadian system for simulation of mission induced time zone shifts.

## Performance Enhancement

Perhaps the primary feature of man that differs from other organisms is his higher order cognitive capabilities (also discussed in Chapter 2) that form the crucial stage between sensory input and enlightened response. Future missions call for examining means to optimize these cognitive processes. That optimization will require research into what cognition really is, how presently defined cognitive skills can be measured and the possible techniques for enhancement as they relate to USAF mission requirements.

Relevant selection criteria need to be established for the individual cognitive and personality characteristics of aircrewmen. Assessment methodologies and instruments need to be developed that validly and reliably differentiate a spectrum of capabilities and styles in terms of cognition, personality functioning, and trainability in specific skills. These can be coupled with mission or aircraft characteristics to provide the best match of man and machine.

Several technical advances in the field of neurophysiology may be applicable to the selection process as well as innovations expected in the next few decades. Since the civilian community will tend to use these only for the detection and correction of pathological processes, it is expected that the USAF will need to direct their use for characterizing features of neural organization and function desirable in fliers and other specialists.

In the past, innate flying skill was demonstrated by performance only. There was, at best, subjective evaluation by flight surgeons of good reflexes and natural athletic ability. A new approach to the problem is to use advanced techniques to identify those elements of neural organization and function which account for having good hands. The new techniques that can be applied to this research are brain electrical activity mapping, BEAM, positron emission transaxial tomography, PETT, and event related cortical evoked response.

## Visual Enhancement

Increasing scientific evidence shows that while optical quality is important in target acquisition, the first stages of the retina-brain system can relate to the capabilities of the pilot to see a target under conditions not directly related to optical quality. New visual tests, both developed and under development, need to be related to performance to create more meaningful visual standards. The research into these new visual assessment techniques has suggested that visual enhancement (increasing the ability to discern and identify objects) is possible. A similar research approach is needed for the other sensory modalities (hearing, touch, etc.) to probe these capabilities in terms of validity, control, and measurement. This research should create performance-based sensory standards and enhancements by determining sensory limits within a performance related quantitative framework. These sensory limits should also be related to mission requirements and the technological limits of the aircraft system. Opportunities for sensory enhancement should be identified and their development pursued.

## Optimization of Duty Time

A crucial element of both the crew selective process and the enhancement of crew performance is the ability to monitor fatigue. Research is needed to identify the physiological indicators of fatigue and to establish criteria for the onset and degree of fatigue. Instrumentation that monitors fatigue by combining these measurements to provide an index of fatigue can then be developed. This accomplished, further research can be pursued that establishes specific mission related fatigue norms that can be used to monitor the crew's performance in flight.

In continuous 24 hour per day, year around operations personnel must be scheduled to provide continuous service. Research is needed to provide the sleep-wake cycle information needed to design duty-rest cycles which least disrupt the sleep-wake cycle and minimize deteriorizations in alertness and performance.

While there is currently an opportunity to apply information about the circadian system to current rest-duty schedules, there is an even greater need for basic research to define the oscillator characteristics of the circadian pacemakers that time sleep and wakefulness and that influence the ability of sleep-wake cycles and physiological and psychological function to readjust to changes in phase shift. In particular, a phase response curve for the human circadian system needs to be defined, the arrangement regulating the human sleep-wake cycle needs to be characterized adequately and mathematical models need to be constructed using coupled oscillator features that can predict the limits of schedule tolerance. Basic research also needs to be conducted using animal models to investigate the factors that determine the rate of adjustment to work-rest schedules. In order to provide a reasonable analogy to man these studies should be conducted in animals that are awake during the day and asleep at night.

## Information Transfer Enhancement

Data management, decision making, and design of data displays require a secure knowledge of the limits of information registry in various working modes. Existing research efforts are exploring relatively low level problems, whereas magnitude is a critical issue. Control of attention in a negative sense, e.g., meditational skills, is still in an anecdotal stage, but would be useful in fatigue prevention via recovery during rest stages.

Research is needed to define the normal range of focused and nonfocused capacity to store data in short and long term memory. Studies of fluctuations of this capacity due to fatigue and/or physiologically disrupting states, such as transmeridianal, diurnal phase-shifting and/or neuropharmacological impairment of central synaptic function, should also be investigated.

The most troublesome area for practical use of computational aids is the user interface. This is especially critical for man-machine integration in aeronautical systems, where data intake rate and decision consequences are likely to be maximally stressed. Because people vary widely in genetic and acquired skill profiles, system displays are designed for a minimal average crew member. Both crew selection and training narrow the variance in operator skills; nonetheless, by definition of the concept of the average, for the most part matches will be suboptimal to some degree.

A method is needed, then, to fine tune the display and control interface of integrated weapons/control systems so that it matches optimally to operator cognitive style. Flight simulators should be designed such that some degree of parametric control of display rates, size, function and sampling distribution is present. When optimal for a given operator, it should be possible to make an insert card that records the flier's optimal parameters. Insertion of the card into an onboard system controller can then set the preferred parameter profile to optimize his flying performance.

## On-Alert Time Enhancement

It is necessary that methods be developed for maintaining a pilot in the alert posture for as long as possible and, at the same time, monitoring when his/her mission completion potential has begun to degrade. Efforts should be made to enhance his alert duration and, as discussed earlier, the optimum duty-rest cycle of the aircrew must be determined.

Psychophysiological research should investigate sympathetic nervous system arousal and determine if this arousal increases or decreases with time. This information, coupled with data from real or simulated launches, can be used to determine the potential effectiveness of missions as a function of on-alert time.

Research into enhancing the number of hours on-alert should consider optimizing schedules and the use of internal enhancement techniques. These techniques may include such relaxation techniques as autogenic training, deep muscle relaxation, autohypnosis and biofeedback as well as such alerting techniques as autohypnosis, mental imaging, and biofeedback.

## Morale Enhancement During Combat

At the other extreme from monotonous standing alerts are the psychophysiological disorders associated with combat. The incidence of these disorders increases when morale is low. Research is needed to develop a means of measuring aircrew morale, which is admittedly a very abstract entity. Methods of enhancing aircrew morale before and during combat are needed as are means for preparing the aircrewman for the fear generated by combat.

## Reliability Enhancement and Aging

In all situations, the reliability of human operations is less than perfect. Operator reliability research is in its infancy, although provocative progress has recently been made due to its application in C³I and the nuclear power generating industry. Research is needed to characterize the components of human reliability and to develop a human reliability model that can serve as a tool for studies as C³I systems evolve.

Related to this are the effects of aging on information processing and decision making effectiveness. C³I centers vary in size, scope of responsibility, breadth of functions, and level of command. Staff rank and experience increases as each of these factors increase. Within a single center, there are also variations in experience, skills, and rank that have an approximate relationship with age. There are no data on changes or variations in effectiveness, if they occur, in the processes of information processing and decision making with age. Research should be directed toward quantifying the changes in the process and effectiveness of information processing and decision making with experience, rank, and age. Training techniques need to be developed that enhance performance in younger operators if age counts, or, in the older operators if deficiencies develop with age.

APPENDIX D.

NUREG/ CR-2833

# Critical Human Factors Issues in Nuclear Power Regulation and a Recommended Comprehensive Human Factors Long-Range Plan

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### 4.5.4 Shift Duration and Rotation

We recommend that research be conducted to determine whether and under what conditions operator performance in the control room measurably deteriorates. Particular attention should be devoted to identifying performance measures and physiological indices that are likely to be sensitive to loss of alertness and cumulative fatigue. Assuming that performance deterioration is documented, research should be conducted to identify variables that influence its severity. Variables to be investigated should include, at least, shift duration, shift rotation schemes, and procedures for eliminating boredom. Work should also be performed on the redesign of the LER methods so that an appropriate and useable data bank of events can be related to independent variables logically associated with shift length, work/rest cycles, and shift duration.

The recommended actions are judged to be of high importance. They should be started within one to two years and require three years to complete. Necessary resources are a total of 10 person-years professional services and access to control room and control room personnel. Personnel requirements include a career human factors professional or experimental psychologist and a work physiologist. The implementation of this research is dependent upon (1) development of unobtrusive, sensitive measures of performance deterioration or long-term alertness, and (2) cooperation of management, union, and plant personnel.

## 4.4 Shift Duration and Rotation

### GENERAL SYSTEM REQUIREMENTS

The system requirement is to provide full staffing 24 hours a day, 7 days a week with operating personnel who are not only competent technically but who are fully alert to indications of changing conditions that may be symptomatic of preaccident states.

### CONSTRAINTS

The shortage of qualified operator personnel in some geographic areas makes it impossible for the utility to meet the requirements for continuous operations without longer than normal industry work shifts. It is reported that the more stringent examination cut-off scores, which have produced a higher failure rate among operators up for requalification, have contributed to this problem.

There are inescapable periods of tedium associated with routine control room operations. The requirement for round-the-clock operations makes it unavoidable, as long as rotating shifts are used, that operational personnel will periodically be exposed to circadian depressions in the level of central nervous system arousal.

### PRESENT STATUS IN MEETING REQUIREMENTS

The power industry is one of the few that requires full operational staffing 24 hours a day, 7 days a week. A natural consequence of the required high level of technical qualifications and current personnel shortages (in some areas) is pressure from industry for shifts of comparatively long duration. Although many plants utilize conventional 8-hour shifts, a significant number employ 12-hour shifts, and under certain circumstances personnel may work considerably longer than 12 hours before being relieved. There are three fundamental safety related questions to be answered:

1. How long can plant operators continuously perform without suffering some degradation in performance? Is the degradation serious?
2. What is the optimal work/rest pattern for a given shift?
3. What is the optimal shift rotation pattern to avoid cumulative fatigue and minimize probable circadian effects on personnel?

Each of these issues is complex and relates not only to safety of operations but to the morale of the working force.

The NRC has provided guidelines with respect to permissible overtime in NUREG-0731 but has not as yet officially addressed performance problems that might occur during routine work days of accepted length. Generally speaking, these guidelines stipulate that individuals shall not be permitted to work more than 12 hours straight; that an individual shall not work more than 72 hours in any 7-day period; and that an individual shall not be required to work more than 14 consecutive days without having 2 consecutive days off. Under certain circumstances, deviations from these rules can be authorized by the Plant Manger.

To date, no confirmatory research has been conducted to indicate whether these recommendations are good, bad, or indifferent with respect to operational safety. Evidence from other industries would suggest that significant performance degradation can occur in considerably less than 12 hours of continuous operations, but there has been no demonstration that this occurs in nuclear power plants. The matter is complicated by the pattern of rest breaks and opportunities for diversion from plant monitoring by periodic assignments to other responsibilities. Satisfactory research on this issue, of course, requires a performance criterion that is sensitive to the effects of fatigue and boredom and, as noted elsewhere, suitable performance measures of continuous operations have not been developed.

There is considerable diversity of opinion expressed within industry concerning both shift durations and shift rotation patterns. Those plants that have experienced a shortage of qualified operating personnel are quick to rationalize the advantages of 12-hour shifts. These include the fact that the operators have grown used to the additional pay they receive for overtime work, that they do not suffer performance degradation because they can still "answer questions sensibly" when coming off duty after 12 hours, that there is one fewer plant turnover every 24 hours, and that the plant personnel are kept alert during the night shift by virtue of the amount of surveillance work that must be performed (i.e., the problems of boredom are averted). The potentially adverse effects of circadian rhythms are recognized by some elements of industry with the result that in at least one utility there is consideration of changing from 7-day shift rotations to 30-day shift rotations. It is anticipated that this plan will be acceptable to plant personnel.

Despite these assurances, it is evident that certain industry practice compounds the possible adverse effects of long shift durations and adverse circadian influences. Whether or not serious performance degradation occurs under these circumstances is, as noted, unknown and suitable research remains to be performed on this issue. It is notable, however, that some regional inspectors report that the only incidents of "true" operator error they had ever observed occurred during the midnight shift.

NUREG/CR-1764 addressed the question of the relative merits of an 8-hour rotating shift versus a 12-hour rotating shift with a shorter work week (4 days per week rather than 5). This study was based on a review of laboratory research and field studies from other industrial and military settings. The implications of these studies for nuclear power plant shift durations were viewed as difficult to establish with confidence, but it was concluded (page 35) that:

> "A conservative interpretation of the studies reviewed in this section would suggest that a change from an 8-hour rotating shift to a 12-hour rotating shift is not a particularly desirable option, and is likely to result in certain types of performance decrements and a decrease in 'performance reserves'. Performance on the night shift is likely to be especially affected by the combined effects of longer working hours and larger circadian rhythm disruptions. Whether these changes in performance have operational significance in the reactor control room environment is unknown."

The authors of NUREG/CR-1750, in noting the contrast between Navy watch schedules and shift durations in nuclear power plants, commented as follows:

> It is our experience that many Navy watches, particularly in the Navy nuclear submarine program, are 6 hours in length and it is not uncommon for personnel at some watch stations to be on a "two-section rotation" (i.e., 6 hours on watch and 6 hours off watch). While we do not find fault with 8-hour watches currently assigned to plant personnel at some utilities, we do not agree with the practice of some utilities that have personnel stand back-to-back 8-hour shifts when an operator from a

> relieving shift does not report due to sickness, etc. Utilities should have firm requirements that personnel stand no more than 12-hour shifts, and that they have at least as much time off between shifts as the length of their shifts. (p. D-12)

The problem of shift duration is compounded by shift rotation practices that require personnel to work on irregular schedules with respect to the 24-hour clock. Reportedly, virtually all of the utilities follow this practice. A particular group of operating personnel will be on the day shift for some defined period (a few days to a week in most instances), then change to the evening shift for a similar period, and then to the midnight shift. After some period of time off, the cycle is repeated.

Ehret and Cahill (30) have made a survey of shift rotation practices in the industry and have concluded that those most commonly in use are those that combine slow rotation with phase advance. They conclude, from both a theoretical point of view as well as experimentation with animals using various rotation protocols, that these conditions assure bad "circadian chronohygiene" and associated poor performance with respect to visual acuity and cognitive requirements of operational tasks. Rotation schedules involving a shift phase change daily, or every other day, are considered to be particularly undesirable though they are widely used. Slow rotation with phase delay is considered better than slow rotation with phase advance.

The influence of natural circadian rhythms on the performance of personnel in a variety of industrial and military settings appears to be quite well established. The general finding is that people on night shifts who are not adapted to working during non-daylight hours are increasingly prone to losses of alertness and degradation of performance, particularly between midnight and 6 AM, with the effect becoming most severe around 4 AM for most people. The more routine and tedious the task, the more likely it is that degradation will occur. Adaptation to a new shift is possible, of course, but circadian effects are persistent and may require several days, or even weeks of work on the new shift before personnel are adapted to the new time period.

Certain nuclear industry practices would appear to compound the possible adverse effects of long shift durations and adverse circadian influences. For example, in one plant visited a four-day 12-on, 12-off watch cycle was employed with phase advance and shift rotation occurring after either one and a half or two and half days off. Using this scheme, the personnel are exposed to quite lengthy watches and the night shift, which begins at 7 PM and ends at 7 AM, combines lengthy watches with the worst period of circadian influence. Whether or not consequential performance degradation occurs under these circumstances is, as noted, unknown and we know of no suitable research that has been peformed in nuclear power plants to address the issue.

## PLANNED ACTIVITIES

NUREG-0660 (I.A.1.3) addresses the problem of ensuring the necessary number and ready availability of personnel to staff nuclear power plant operations shifts. The program plan includes (a) an investigation of the need to develop requirements for the total shift complement, as opposed to solely licensed and unlicensed operators and (b) studies regarding shift length, shift rotational schemes, and the use of overtime. The latter are to reflect the results of RES studies and other information, and feedback from industry, to develop a revised staff position on shift staffing, if necessary, and issue guidance to industry. This work is to continue through FY83 with guidance to industry scheduled for mid-FY84.

It is recognized within the NRC that there is a need to establish a "more rigorous scientific basis" for deciding what is acceptable from the standpoint of shift length, shift rotational schemes, and the use of overtime in nuclear power plants (Denton memorandum, March 27, 81). A program is called out to (1) critically evaluate what is known about shift length, shift rotation, and overtime use on operator performance and (2) conduct basic research, as needed, with human subjects to determine optimum methods for minimizing the deleterious effects of shift rotation, length, and overtime on operator performance.

The NRR priority list showed this item as number 10 in a list of 16. Current work includes in-house analysis of LERs to determine their relationship to shift work variables. An earlier review of overtime data proved "inconclusive." LERs are being examined for potential correlations between error frequency and time of day. The RES staff has drafted an experimental design to examine effects of shift work and rotation schedule but, prior to its implementaton, they are awaiting additional evidence that working hours are "dominant performance-shaping factors." It is hoped that some of this evidence will be forthcoming from outside programs (such as NASA's study of pilot fatigue).

The Department of Energy is sponsoring work at Argonne National Laboratory on how to adapt most rapidly to a new shift with minimum disturbance. In particular, these investigators are studying dietary practices which are designed to accelerate circadian phase shifts. This work, which is being done on animals, investigates the influence of consuming meals on "days off" of a type and at times which anticipate the next shift schedule.

## MISSING ELEMENTS

The key element in these planned activities is the need for development of a performance criterion measure that is sufficiently sensitive to detect changing levels of operator alertness as a function of time on the job and time of day. While it is certainly worthwhile to try to relate LERs to shift duration, overtime, and possible circadian effects, failure to detect these influences in the LERs may simply mean that the LER reporting system is not properly designed to detect them. Or, as in the case of accident research in other industries, it may be that only a very carefully defined subset of operator behavior is related to shift duration and rotation practices.

## TECHNICAL FEASIBILITY AND PROBLEMS

It is a considerable technical challenge to develop criterion measures that are sensitive to momentary lapses of attention or progressive changes in levels of alertness. Ideally, the performance measure should be derivable from routine control room activities. Since the operators are not engaged in continuous control room activity, however, some form of secondary task may have to be introduced. There is a substantial literature on this technique, which generally indicates that considerable sophistication must be used in introducing a secondary task if the investigator is to avoid intrusion, i.e., changing the phenomena he wishes to observe.

## INTERACTION WITH OTHER SYSTEM REQUIREMENTS

The problems associated with shift duration and rotation and the associated problems of maintaining operator alertness interact with selection criteria, qualifications criteria which fundamentally limit the supply of operator manpower, and with the human engineering of control room displays, which can be designed to some extent to circumvent operator loss of alertness to changing plant conditions.

## RECOMMENDATIONS

Loss of operator alertness and any adverse change in cognitive functioning must be viewed as one of the most consequential performance shaping factors in nuclear powerplant operations.[1]

1. Research should be conducted aimed at determining whether and under what conditions operator performance in the control room measurably deteriorates. Particular attention should be directed at identifying cognitive variables (information processing), performance measures, and physiological indices that are likely to be sensitive to loss of alertness and cumulative fatigue (see Section 1.8).

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[1] A recent review of research on human vigilance (67) suggests that the answers needed by the NRC and the power industry on performance degradation as a function of watch schedules are not likely to be found in existing research literature. This is essentially the viewpoint also expressed in NUREG/CR-1764.

2. Work should be performed on the (necessary) redesign of LER reporting methods so that an appropriate data bank of events can be related to various independent variables logically associated with shift length, work/rest cycles, and shift duration.

3. Assuming that performance deterioration is documented, the NRC should conduct research to identify variables that influence its severity. These variables should include, but not be limited to, shift duration, shift rotation schemes, procedures for alleviating boredom, and so forth.

Importance: High

Schedule: Urgency - start within 1-2 years

Duration - 3 years

Resources: 10 person-years; access to control room and control room personnel

Implementation: Qualified human factors specialist or experimental psychologist; work physiologist

Dependencies: Development of unobtrusive sensitive measures of performance deterioration or long alertness. Cooperation of management, union, and the personnel themselves.

Mr. GORE. Thank you very much. I found that fascinating.

Let me ask you first of all about a statement you made. You said that the shift change cycle that was being used by Great Salt Lake at the time you were consulted was the most common in America?

Dr. CZEISLER. In American round-the-clock operations, from chemical plants to manufacturing plants to utilities, it is the most widespread schedule that we have found in use at that time or since then.

Mr. GORE. That is interesting.

And you said, Mr. Nielsen, that it was exactly the same as the work schedule that Gordon Thompson outlines in his testimony, and that he prepared in the schedule that is attached to his testimony. It is that exact same schedule, right?

Mr. NIELSEN. Yes. sir, it is identical.

Mr. GORE. And that is the single most common shift change schedule you used?

Dr. CZEISLER. Yes; there are minor variations. The direction of rotation may change. The number of days off between days and evening shift or between evening and night shift, when the long change occurs, all these things are slightly variable. But it is all the same type of weekly rotation schedule.

Mr. GORE. Yes.

Dr. CZEISLER. When we change simply the direction of the rotation alone, even though that would conceivably be more compatible with the natural tendency of the sleep-wake cycle to drift to later hours, there were no statistically significant improvements on any of the scales when only the direction of the rotation was changed.

It is a bit, Mr. Chairman, as if you might think of driving 10 miles an hour against traffic on an expressway. It might help for you to change the direction and to go 10 miles an hour with traffic, but it wouldn't be all that much safer on an expressway to be traveling at so much the wrong speed. Basically, you have to be up to the correct speed and in the correct direction.

Mr. **Gore**. Depending on which lane you were in, it might be a good deal safer.

Dr. **Czeisler**. That is right.

Mr. **Gore**. What are the simple rules that we now know of? I take to heart your statement that there is a great deal we don't know and much more research need to be done. But do you agree with the simple rules that I outlined earlier? How would you state them?

Dr. **Czeisler**. Since they come directly from——

Mr. **Gore**. From your work, there is no reason for you to disagree with them.

Dr. **Czeisler**. That is right. Those were the principles which we attempted to introduce in that situation. They are based on research from basic physiological human studies, as well as research that has been done on a variety of other species.

But what is currently missing at the present time is development of performance criteria which could actually simulate the types of work that is required in continuous round-the-clock operations through industry. In power plants, in control rooms—such as they have at Great Salt Lake Minerals or any chemical plant—in news print manufacturing facilities, in Air Force planes, all around this country and throughout the world, people are watching video display screens and trying to chart trends of performance of whatever equipment they are trying to monitor throughout the day and night.

We in the laboratory don't have that kind of equipment to be able to simulate the actual problems that are being faced by workers, so we are forced instead to have them adding up serial sums of numbers or performing various other performance tasks to try to find out how changes in their shift work schedules might affect their performance at work. What I feel is a very high priority is to try to make the laboratory research more relevant to the actual work place settings and to begin to simulate the kinds of schedules that we are introducing and see how we can begin to take the training wheels off and get some control over the operation of this new technology.

Mr. **Gore**. Let me see if I understand the rudimentary scientific principles on which your work is based. I know this is thin ice, but if you will help me along, maybe I can understand them.

When you use your freeway example, traveling 10 miles an hour in a direction opposite to the traffic on the freeway, how would you shift that over and use that same example with circadian rhythms. Incidently, you say that body clock is on a 25-hour cycle—isn't that correct, 25 hours?

Dr. **Czeisler**. We normally reset our biological clocks every day by about an hour in order to maintain an exactly 24-hour day. But left to its own devices, you are absolutely correct, that the free-running period or the natural tendency of the sleep-wake cycle is to drift to later hours. That is why on weekends we tend to go to bed a little later, on Friday night, let's say, and wake up a little later on Saturday morning and go to bed a little later on Saturday night.

Mr. **Gore**. That may be one reason you stay up later on weekends.

Dr. **Czeisler**. In fact, if that were not a basic property of our biological clocks, we would probably, on our days off, tend to go to bed earlier and maybe have our parties in the mornings. It certainly is true of other species which have shorter than 24-hour periods. Not that they have their parties in the morning, but, left to their own devices, when they don't have a schedule being imposed from the outside, they do tend to move their activity to earlier and earlier hours.

Mr. **Gore**. OK.

Let me try to restate that. The way the human body works, if you remove all external cues, like the sunrise and alarm clocks, and have an experiment where people don't have any cues or guidelines, then you find that the body clock will drift on to a 25-hour cycle. But as a matter of fact, what happens with most people who are not involved in shift work is that every single day that 25-hour body clock is readjusted again and gets back on a 24-hour cycle because is constantly reset; is that correct?

Dr. **Czeisler**. That is right.

Mr. **Gore**. In fact, there are lots of different body clocks inside the human body, some having to do with the digestive system, some having to do with brain waves, some having to do with other body functions, and when the body clock is reset on a daily basis, all of these variable clocks are synchronized or entrained so that they worked together on the same 24-hour cycle that you choose to use, correct?

Dr. **Czeisler**. Exactly correct. I am impressed.

Mr. **Gore**. Help me along here now. Going back to your freeway example, which may be a complicated example to use, the normal 25-hour cycle would be like moving 10 miles per hour down the freeway, you are moving forward 1 hour per day—or at least the momentum is forward if you don't constantly reset your body clock, right?

Dr. **Czeisler**. OK; let's say we are on a side street and we are moving forward here. The freeway analogy is a little complicated because we have one going fast when the other——

Mr. **Gore**. OK, let's scrap that.

Dr. **Czeisler**. Let's say we are on a side street and you are going 10 miles an hour with traffic, but your schedule is requiring you to go 60 miles an hour against traffic.

Mr. **Gore**. I began to realize the example is probably a complicated one. Let's just scrap the example and go at it in a little different way.

The 25-hour cycle means that you are moving forward, or you have the capability of moving forward an hour per day without disrupting your body clocks.

Dr. **Czeisler**. I can show you a figure if you would like.

Mr. **Gore**. Let me finish this, and then I will ask you to do that.

But you have the natural capability to advance 1 hour per day without disrupting your body clocks. If your shift rotation requires you to move in the opposite direction, you are moving against that normal flow.

Dr. **Czeisler**. That is exactly right.

Mr. **Gore**. But if you move forward, then that natural ability of the body to move forward at least 1 hour without disrupting the body clocks means that you are moving with the flow, so it is a little bit easier to adjust; is that basically it?

Dr. **Czeisler**. That is basically it. That is the story to the first approximation, which is what we were forced to introduce at GSL because that is all of the information that was available.

Mr. **Gore**. So, in other words, as a researcher, you knew that much, but there had never been any real-life experiments on a big scale. So you took what you knew and went and responded to Mr. Richey's request—"I am a factory manager, I want your help, Mr. Scientist. Tell me how to design these shift schedules." You said, "What we will do is we will get with that flow and we will just advance them 1 hour each day."

Dr. **Czeisler**. Right; and that turned logistically out to be a nightmare. So then we continued to have the abrupt changes in shifts. But we have them at least going in the correct direction and we kept the people on steady shifts for as long a period of time as it was convenient.

Mr. **Gore**. Yes.

Dr. **Czeisler**. Shall I go to the board for a second?

Mr. **Gore**. All right.

[Slide.]

Dr. **Czeisler**. The situation is complicated by two factors, Mr. Chairman. The first of those is the fact that, even on a schedule where an individual is kept on steady shifts for several weeks before rotation, of course, there are days off which interdigitate with the several weeks of steady shifts. So the people shift back and forth from, let's say, working at night for a 3-week stretch and trying to have a couple of days off. As I am sure Mr. Neilsen would be willing to testify, shifting back and forth on your days off, even on the schedule which we introduced at GSL, still poses a significant problem in trying to provide a time for the individual worker to adjust to the changes in shift and to the changes in family and social life when they try to take advantage of those days off.

But the basic information that we were going on when we tried to introduce these concepts at GSL were, first of all, if we study a person living in a special environment where there are no clocks, no radios, no information sources as to the time of day—a bit like this hearing room, except without the windows and without the clock on the wall, where you could be here and not necessarily know what time of day it was on the outside—this represents the time of day on the top of this graph, this being midnight, this being noon. This represents a time when we schedule the individual to go to sleep every day at the same time, which was midnight, and to wake up every morning at about 7 o'clock in the morning.

As you can see, the heavy black bars represent polygraphically verified sleep by those EEG-type measures that I already discussed. You can see that the person was able to maintain consolidated sleep every night with only occasional interruptions in that daily sleep episode for the first 3 weeks of the study when we were scheduling his sleep to be occurring at that time.

[Slide.]

Dr. **Czeisler**. When we said that the ball was in his court at this point, that he could go to sleep whenever he wished and wake up whenever he wished——

Mr. **Gore**. This is a room with no windows and no——

Dr. **Czeisler**. And no clocks. It could be deep in a cave. It happens to be on the top floor of a hospital in New York. There are no clocks, no radios, no information sources as to the time.

Mr. **Gore**. No traffic noise?

Dr. **Czeisler**. Well, traffic noise throughout day and night.

In this situation, the specially sound-attenuated rooms, and so on, the natural tendency of the sleep time is for the sleep time to drift to later hours and for the wake time to drift to later hours, with an average period length of about 25 hours. This has been done in hundreds of studies of human beings living in environments, from caves to bunkers, to facilities like the one where this was carried out, and the period length in man is always about 5 to 10 percent longer than the 24-hour day. That is to say that it is about 25 or 26 hours.

Every species has a characteristic free-running period length. Some species are shorter than 24 hours, and some have a longer period than a 24-hour period, like the squirrel monkey that Dr. Moore-Ede will be describing this afternoon which has a length of about 25 hours.

[Slide.]

Dr. **Czeisler**. Now the thing that begins to complicate this picture—and this slide illustrates this—is that if we study people for long enough in this environment—and I don't know whether you can sharpen this up—but suffice it to say that the black bars here represent the sleep time in a graph very similar to the one I just showed you except it is smaller. If we study people for long enough, like for several months instead of several weeks, the two different oscillating system in the body, or two different pacemakers in the body, which control different physiologic functions, the timing of those two systems splits apart.

This is probably what is happening when people are doing shift work and when they are rotating between days off, on weekends, or between whatever, these two systems in the body are splitting apart. We can have them split apart under this kind of laboratory condition, and the next slide shows how they begin to interact.

[Slide.]

Dr. **Czeisler**. This is the same data replotted so that you can see that the sleep times are normally coincident with this red area which is when the troughs of the daily cycle of body temperature, alertness, and performance are occurring.

Mr. **Gore**. Wait a second. The two separate internal body clocks that you are describing are, one, the sleep-wake cycle——

Dr. **Czeisler**. One has to do with the activity-rest cycle, or the sleep-wake cycle in the broadest sense, although the timing of certain stages of sleep go with the other oscillator.

Mr. **Gore**. The second internal body clock is body temperature, which also corresponds with alertness, did you say?

Dr. **Czeisler**. Yes; with alertness and performance on psycho motor tasks. That trough in the body temperature cycle is what is correlated with the increases in the truck accidents, correlated with the increase in errors in reading meters, correlated with the other performance decrements that I discussed earlier.

So what happens is that these two cycles can split apart. This is the only reason you are even able, in some small sense, to adjust to jet lag. When you cross time zones and you think you are able to sleep at the new time, you have shifted this very labile oscillator, which controls the rest-activity cycle, so that you are now "sleeping" at the new phase of the cycle, but you have not shifted this much more labile oscillator.

[Slide.]

Dr. **Czeisler**. This is an individual we studied for 6 months in this environment. The black bars here represents the troughs in the daily cycle of body temperature. This is the time when the temperature is below its normal means. This would be the time when the performance and the alertness, and so on, would be at their minimum.

For the first 3 weeks of the experiment, again, we scheduled the subject's activity-rest cycle when he was sleeping and waking, and we could synchronize that temperature cycle and all of its correlates to an exactly 24-hour period. But when we allowed the subject to free run here, despite the fact that the period length of his sleep-wake cycle, which is the much more labile oscillator, drifted from 25 to 30 to 40 to 50 hours in period length. That means he would be up 20 to 30 hours, asleep for 5, 10, 15, or 20 hours.

Despite the fact that the sleep-wake cycle was completely desynchronized from this cycle, you can see how very regular the timing of the body temperature persisted throughout the 6 months of this experiment. In fact, if you take any month-long chunk of this experiment, the period length of the body temperature cycle never varies by more than plus or minus 2 minutes. So we have a very precise pacemaker that is ticking off the hours.

In fact, Prof. Richard Kronauer, a professor of engineering and applied physics at Harvard and a specialist in oscillator theory who has done mathematical modeling of this with us, contends that it would be very difficult to construct a mechanical oscillator which would be as precise as this biological oscillator which we have within our brains, which Dr. Moore-Ede will describe.

Dr. **Czeisler**. Now, the problem is that these types of work schedules—and what the witness earlier today from the Prince George's Police Department testified, that even though now he is no longer working at night, he finds that his sleep time is drifting to later hours, that may have to do with the fact that the period length of this cycle and its capacity to adjust to changes is dependent, in part, on the previous history.

In other words, what has happened in the previous year or two. So the capacity of this system to adjust, as well as its intrinsic period length, may be affected by prior regimens of shifts.

Mr. **Gore**. So that is why he automatically wakes up at 1 p.m.?

Dr. **Czeisler**. This cycle was probably drifting around the clock. In fact, the next slide shows how the length of sleep and the ability to sleep varies with the phase of that temperature cycle at which we try to go to sleep.

So when the pilot was complaining that on one run he was having to get up at 6 o'clock in the morning and fly for five segments and then the next day he was supposed to fly at night and sleep during the daytime, and the next day he was supposed to sleep at night and sleep during the daytime, it is completely impossible for this timing system to adjust to those types of changes.

[Slide.]

This slide illustrates—this was an experiment where people were actually put on a schedule, which we would never recommend, where they were awake for 2 hours, allowed to sleep for an hour, awake for 2 hours, allowed to sleep for an hour, and so on, round and round the clock for 10 days.

Mr. **Gore**. So that would not only explain why the policeman wakes up automatically at 1 in the afternoon, it might also explain why at 4 or 5 in the morning there is a ninefold increase in truck accidents.

Dr. **Czeisler**. That is exactly right.

Mr. **Gore**. Of course, we don't know the effect at Three Mile Island, but the fact that the operators there, who were supposed to be looking at the controls, were at that point in their cycle when they would be the least alert and most likely to have a waking nap.

Dr. **Czeisler**. That is exactly right. So at this point in the cycle, the trough in the body temperature cycle, that is when the people are able to sleep 75 percent of the available time in these little 1 hour chunks, but when you put people to bed at the crest of their body temperature cycle, they are able—despite the fact that they are significantly sleep-deprived after 10 days on this kind of a crazy schedule, they can only sleep 10 minutes out of every available hour when they are put to sleep at that phase of the cycle.

So you take somebody, you have them working all night, you try to put them to bed at the wrong phase, even if they can get to sleep, they are awakened prematurely because the rising phase of this cycle, the upswing of this cycle, is when the internal alarm clock goes off.

That is when our body clock wakes us up, and regardless of whether you have been awake for the previous 24 hours, and whether you are sleep deprived, this timing system still wakes up at that point in the cycle.

The next day, even if you have slept during the day, even if you have taken sleeping pills, or whatever other measures you may have used, this internal clock will still be winding everything down and resulting in minimum in alertness and performance at that time of day.

Now, it was our attempt to take this information in the capacity that we had learned how to begin to tinker with these internal clocks and to reset them by shifting them in directions to which it was most easy to adjust, to begin to apply that information to try to have people working not at the trough of their body temperature cycle and trough of alertness and trough of performance, but try to shift that into the time when they want to be sleeping anyway and to keep them working even at 4 o'clock in the morning at the crest of their alertness and performance cycles.

But we are only at a very first approximation in that, because it is a very complicated, multioscillator system that we are dealing with, and we need to be able to simulate these schedules in the laboratory and physiologically record, which we were not able to do at GSL, what the outcomes were.

Mr. **Gore**. Well, even with the rudimentary knowledge that you have gained so far, you were obviously able to produce dramatic results at this company, both with respect to the company's productivity and with respect to the subjective experience of the employees there.

I congratulate you on that, and I wish you well in your future work.

I want to recognize my colleague, Congressman McCandless.

Mr. **McCandless**. I found this rather fascinating, particularly this body temperature period and the 24-hour clock.

For purposes of our discussion let us take a scenario of 3 shifts, 8 to 4, 4 to 12 and 12 to 8, The fact that your studies indicate the critical period in those three shifts is on the graveyard shift, I come back to possibly some of my own experiences over the years, for whatever it might be worth, that the environment—work tempo, the activity level, temperature of the room, activity of lack of activity around me—all had a direct bearing. These factors could have a direct bearing on the individual in either encouraging or discouraging that particular phase at that particular time on that particular shift.

I am trying to relate what you said to these kinds of external influences on the body in addition to what you are saying is an internal influence.

Dr. **Czeisler**. Yes, I think, Congressman McCandless, that these are critical factors and it is even beyond the external factors that you have mentioned.

It also has to do with the timing of meals, for example, which are often not available—regular, hot meals are often not available in a work environment where people are operating around the clock.

The most that may be available is the sort of thing that you can get from a vending machine. But the timing of meals, the stimuli from the environment and a host of other factors, I think, must be taken into consideration in investigating these issues.

This is precisely why I feel it would be very important to link up laboratory studies with the actual types of situations that the people are working, instead of having, in the studies that we do in the laboratory, be rather contrived situations, which don't reflect the reality.

Because if we are going to try to effect these physiologic functions and try to see how we can effect the timing of the release of hormones and the timing of the variety of other physiologic functions that may be required in order to allow an individual to operate at maximum alertness and performance, then we are going to need to be able to correlate these factors with the kinds of real life situations that are confronting the workers at their work site.

Mr. **McCandless**. I would hate to have this, Mr. Chairman, lead to some type of slight shock in a chair at a control panel that is administered on the quarter hour between 5 and 7 in order to keep the individual alert and is responsible for watching the meters or something. [Laughter.]

I think we can go at it in another way.

Thank you very much, Mr. Chairman.

Mr. **Gore**. Thank you.

Now, so I have it clear in my own mind, you, first of all, tried to adjust these shifts an hour or an hour and a half forward each day or each week?

Dr. **Czeisler**. No. The shifts were kept at steady hours, except during the week when the shifts were to be changed. We are only talking about a minor portion of the schedule here.

In other words, every 3 weeks the shifts change, and that change—it is a matter of accomplishing that change in one day versus accomplishing it in 4 days.

If you do it an hour and a half a day, you can accomplish the shift change—well, it would be 5 days later that you would have accomplished the 8 hours of shift.

Mr. **Gore**. Wait a second. What exactly is the shift change schedule that GSL is using now?

Dr. **Czeisler**. They work steady shifts for 3 weeks before rotating from day shift onto evening shift, and they do the rotation in an abrupt manner because operationally that other kind of schedule which we only did for two changes in the last 2 years, the first two, simply did not work.

Mr. **Gore**. Now, the two simple rules that we can state with some certainty now at this rudimentary stage of the research are, No. 1, the frequency of shift change should be slowed down so that there is a longer period of time for people to adjust their body clocks; No. 2, when the shift is made it should be a shift forward and not too far forward.

Is that correct?

Dr. **Czeisler**. Yes, Mr. Chairman.

Mr. **Gore**. All right. Now, the most common form of shift rotation currently used in America is totally contradictory to both of those simple rules; correct?

Dr. **Czeisler**. The most common type of shift work schedule used in the United States is certainly contrary to the second one of those rules, which is that it rotates typically every week. I would say it is six of one and half a dozen of another as to which direction it rotates, since this evolved on the basis of industry practice, local tradition or various concerns which had nothing to do with how these internal timing systems in the body functioned.

Mr. **Gore**. Mr. Richey, why were you using the other rotating system before you became so aware of the complaints among your employees and before you consulted Dr. Czeisler, how had you developed that old shift rotation system?

Was it just force of habit?

Mr. **Richey**. Actually, the plant general foreman that was hired when the place was built—it was only built about 13 years ago—brought that with him from his old plant. When it came to say what kind of a schedule do we use, he said, "this is what we used at the last place", and so it was propagated that way.

Mr. **Gore**. I see. Well, that is probably how it has been propagated all over the country, just on that basis.

Mr. **Richey**. Interestingly enough, as I have talked to people all over the country, and there has been a lot of people that have called me and asked me about our shift schedule, I have always asked them, well, what are currently working.

So this is kind of a subjective survey. But interestingly enough, the number of people that go the direction that we were going, the delay direction, is in excess of the number of people that go in the forward direction for whatever reason.

So in my opinion, it is not quite split 50-50. There is a preponderance of people that are going the wrong direction.

Mr. **Gore**. Ok. Mr. Nielsen, just to underscore your testimony, it is not just the productivity increases and the rates of potash harvest that are improving dramatically, it is also how you and your fellow coworkers feel about the whole thing.

There are fewer complaints and you feel better about this system; correct?

Mr. **Nielsen**. Yes, sir, I do, and I think they go hand-in-hand with one another. You can't have increased productivity without an increase in morale and general attitude.

Mr. **Gore**. One other question, Mr. Czeisler. On page 1 of your written testimony, you say that errors of inattention are not detected by existing tests. What are the implications of this for previous research that has been done in critical occupations like air traffic control, airline piloting and nuclear powerplant operation?

Dr. **Czeisler**. Well, Mr. Chairman, as is stated in the report to the Nuclear Regulatory Commission, and I quote:

> A recent review of research on human vigilance suggests that the answers needed by the Nuclear Regulatory Commission and the power industry on performance degradation as a function of watch schedules are not likely to be found in existing research literature.

They indicate that this is the same viewpoint as in previous reports. What I wonder about is why something isn't then done about that.

Mr. **Gore**. Let me see if I can pin down why that is the case. When you use the example of the truck driver who took a nap while he was driving for 20 minutes, I assume that that is not really a nap as we commonly think of it. It is what? Something between——

Dr. **Czeisler**. Well, the brain is sleeping while the person is driving.

Mr. **Gore**. I see. After that 20 minute period is over, would that person subjectively state that he had been taking a nap?

Dr. **Czeisler**. He may not be aware of it, and that is one of the most alarming aspects of these kinds of problems is that workers who are on these types of schedules and who have been rotating on them for many years are often completely unaware of the serious degradations in performance, and they, themselves, often do not perceive the extent of the vigilance deficit.

Mr. **Gore**. Now, so a research protocol which relies on asking that person whether or not he or she has just taken a nap will not identify the periods of brain sleep or whatever you want to call it—you referred to it as a nap there—that won't be picked up, because the person won't say, "I was asleep."

Dr. CZEISLER. They won't necessarily be aware of it. I think that one of the reasons why the workers at the Great Salt Lakes Minerals Company were particularly aware of the decrements in their ability to sleep off the job and in their performance at work, as compared to workers in other round-the-clock operations in the United States, was because every summer they don't work shift work.

They go back onto a regular daytime schedule while the—and you can correct me if I am wrong—while the material in the evaporation ponds is——

Mr. RICHEY. Cooked up.

Dr. CZEISLER. Cooked up; right. While the evaporation ponds are evaporating, essentially, over the summer.

So because of the fact that they don't work shift work over the summertime, they get back into a regular schedule. They begin to remember what it was like to be alert during the daytime and to be able to sleep at night, such that they can then recognize the contrast when they go back onto rotating shifts, just like the person who testified first this morning, saying if he had to go back on rotating shifts, he would quit his job.

Now, one of the problems that we have when we go into a situation where people are working rotating shifts 365 days a year, 7 days a week, is that those individuals no longer perceive the decrements associated with the shift work, and we need to develop techniques in the laboratory where we can simulate these types of work schedules so that we can then, with our recording equipment, be able to record exactly what is happening, whether people are having these episodes, and whether when we introduce changes in the work schedule, we can reduce the frequency of that type of problem occurring.

Now, the current attitude is, good, we don't want to go in and document the fact that a powerplant operator is sleeping at work because, think of the liabilities involved. The current NASA study, for example, on airline pilots, they have completely avoided doing EEG studies with the ambulatory monitors such as I just described here with the train drivers or with the expressway drivers because they don't want to find out that people are sleeping in the cockpit.

But I think that to limit what we are going to look for so that we don't find something that we don't want to see is the problem in going about this research if we are going to aim to try to introduce changes which are going to reduce objectively the decrements in vigilance and performance which are obviously going to be found.

Mr. GORE. Now, specifically, coming back to the point that I was trying to make, these past studies of nuclear powerplant operators and airline pilots point out the dangers associated with constantly disrupting the circadian cycle, but you are saying they may dramatically understate the problem because they don't identify the times when powerplant operators and pilots are actually asleep for all intents and purposes; their brains are asleep even though they may keep their eyes open during that time.

They don't identify those periods because they haven't done the tests and they are concerned about what they might find.

Dr. CZEISLER. Yes; in fact, there was an incident where an airliner actually—I believe it was cargo aircraft—was flying from the east to the west coast and flew out over Los Angeles and failed to land at the airport and was going about 100 miles offshore toward Hawaii when the control tower became very alarmed and wondered why—realized they didn't have enough fuel to make it to Hawaii and wondered why they were not following the due course, signaled an alarm in the aircraft only to find that actually all three pilots were asleep at that time.

Now, what I am suggesting in the way of simulators is that we could do a lot of this type of research in the laboratory if we had the same types of consoles and screens to simulate the tasks that the workers in these situations are being asked to perform.

It became clear to me when in going around to these types of plants and in going around to various places in industry with round-the-clock operations that the tests that we use, having people add sums of numbers or having them respond to bleeps on some sort of a vigilance detector, were relatively inconsequential as compared to the task that the people were being asked to perform.

Mr. Gore. So we need two things. We need more research, but we need better utilization of the knowledge that has already been gained from the research which has been done, and when you talk with these factory workers and policemen and nurses and airline pilots and powerplant operators and find out that the most common shift rotation system in America today flies in the face of the elementary principles that have been established, it is obvious that we need better utilization of that knowledge, even as we pursue more and better research.

I would like to thank all three of you for participating here today. We are going to have to move on to our final panel and end the day's hearing.

But I would like to close by thanking this panel very much and wishing you all the best of luck and even better productivity gains, and again, our thanks for helping us develop this hearing and for your testimony here.

Thank you very much.

Mr. Gore. Our final panel is made up of Dr. Martin Moore-Ede, professor at the department of physiology and biophysics at Harvard Medical School and Dr. Thomas Wehr, Acting Chief of the Clinical Psychology Branch at the National Institute of Mental Health in Bethesda.

I would like to welcome both of you, and Dr. Martin Moore-Ede, we would like to begin with you. Without objection, the entire text of your prepared statements will be put into the record at this point, and I would like to invite you now to proceed.

Is that a model of the human brain that you have got there?

[The biographical sketch of Dr. Moore-Ede follows:]

# CURRICULUM VITAE

## MARTIN CHRISTOPHER MOORE-EDE

| | |
|---|---|
| Born | November 22, 1945, London, England |
| 1967 | B.Sc. (First Class Honors) in Physiology, U. of London, England |
| 1970 | MRCS, LRCP, Royal Colleges of Surgeons and Physicians, England |
| 1970 | M.B., B.S., Guy's Hospital Medical School, U. of London, England |
| 1974 | Ph.D. in Physiology, Harvard University |

### Professional Experience

| | |
|---|---|
| 1968 | Research Associate, Stanford U. at NASA Ames Research Center |
| 1970 | Instructor in Physiology, Guy's Hospital Medical School, London, England |
| 1970-1971 | Intern, Toronto East General Hospital, Toronto, Canada |
| 1971-1974 | Research Fellow in Surgery, Harvard Medical School at the Peter Bent Brigham Hospital, Boston |
| 1971-1973 | Frank Knox Fellow of Harvard University |
| 1974-1975 | Associate in Surgery (Physiology), Harvard Medical School |
| 1974- | Consultant in Surgery (Physiology), Peter Bent Brigham Hospital |
| 1975-1980 | Assistant Professor of Physiology, Harvard Medical School |
| 1981- | Associate Professor of Physiology, Harvard Medical School |
| 1982- | Associate Staff-Surgery (Physiology), Brigham and Women's Hospital |
| 1982- | Physiologist, Department of Surgery, Brigham and Women's Hospital |

### Academic Awards

| | |
|---|---|
| 1966 | Second Junior Proficiency Prize, Guy's Hospital Medical School |
| 1966 | Pembrey Prize, Guy's Physiological Society |
| 1967 | First Class Honors in Physiology (B.Sc.) |
| 1971-1972 | Fellow, Frank Knox Fellowship, Harvard Medical School |
| 1971-1974 | Fellow, Science Research Council (British) |
| 1972-1973 | Warren Fellow, Harvard University |
| 1973 | Cate Award for Scholarship |
| 1975-1977 | Andrew W. Mellon Faculty Award, Harvard Medical School |
| 1977-1982 | NIH Career Development Award |
| 1979 | Runner-Up: Most Outstanding Professor Award, H.M.S. Class of '82 |

### Professional Affiliations

| | |
|---|---|
| 1972- | American Association for the Advancement of Science |
| 1973- | American Federation for Clinical Research |
| 1974- | International Society for Chronobiology |
| 1974- | American Physiological Society |
| 1975- | British Interplanetary Society (Fellow) |
| 1976- | American Society for Photobiology |
| 1978- | Aerospace Medical Association |

CURRICULUM VITAE - Continued

MARTIN CHRISTOPHER MOORE-EDE

| | |
|---|---|
| 1978- | Federation of American Scientists |
| 1979- | Federation of American Societies for Experimental Biology |
| 1979- | Sleep Research Society |
| 1980- | The Endocrine Society |
| 1980- | Society for Neuroscience |

## Editorial and Administrative Functions

| | |
|---|---|
| 1979- | Editorial Board: American Journal of Physiology: Regulatory, Integrative and Comparative Physiology |
| 1979- | Executive Board Member, Harvard Medical Society |
| 1979- | Member, Board of Counsellors, M.D.-Ph.D. Program, Harvard Med. School |
| 1979- | Division of Medical Sciences Faculty Representative to Faculty of Arts and Sciences, Harvard University |
| 1980-1982 | Chairman, Harvard Medical Society |
| 1981-82 | Course Director, Physiology 700, Harvard Medical School |
| 1981-84 | Member, Preclinical Promotion Board, Harvard Medical School |
| 1981-84 | Member, Standing Committee on Educational Evaluation, Harvard Medical School |
| 1981- | Member, Faculty Advisory Committee for Planning Teaching Facilities, Harvard Medical School |
| 1982- | Chairman, International Union of Physiological Sciences Commission on Circadian Rhythms and Sleep Physiology |
| 1982- | National Research Council Space Science Board, Space Biology and Medicine Committee |
| 1982- | Associate Editor, *American Journal of Physiology: Regulatory, Integrative and Comparative Physiology* |
| 1982- | Member, Committee on Instructional Implications of Information Technology, Harvard University |
| 1982- | Consulting Editor, *International Journal of Chronobiology* |
| 1983- | New Pathway Working Group on Skills, Harvard Medical School |

## Publications

### Books

Moore-Ede, M.C., Sulzman, F.M., Fuller, C.A. *The Clocks That Time Us: Physiology of the Circadian Timing System.* Cambridge, Ma.: Harvard University Press, 1982.

Moore-Ede, M.C., Czeisler, C.A., Eds. *Mathematical Models of the Circadian Sleep-Wake Cycle.* New York: Raven Press, In Press, 1983.

Czeisler, C.A., Moore-Ede, M.C., Weitzman, E.D. *Circadian Clocks in Man: Timekeeping in Health and Disease.* New York: Raven Press, In Preparation, 1983.

In addition, the publication of more than 60 articles in scientific publications.

## STATEMENTS OF MARTIN C. MOORE-EDE, M.D., PH. D., ASSOCIATE PROFESSOR, DEPARTMENT OF PHYSIOLOGY AND BIOPHYSICS, HARVARD MEDICAL SCHOOL, AND THOMAS A. WEHR, M.D., ACTING CHIEF, CLINICAL PSYCHOLOGY BRANCH, NATIONAL INSTITUTE OF MENTAL HEALTH

Dr. MOORE-EDE. It is, indeed, Mr. Chairman.

Mr. GORE. All right. You have captured our attention. Please proceed.

Dr. MOORE-EDE. Thank you. Mr. Chairman, members of the subcommittee, I am Dr. Martin Moore-Ede, associate professor of physiology at the Harvard Medical School. I currently serve as chairman of the international commission on circadian rhythms and sleep physiology, and I am chairman of the international scientific advisory board of the center for design of industrial schedules.

The 24-hour-a-day society has swept the citizens of the industrialized world into a lifestyle for which our bodies were not designed. You have heard today testimony which concerns the health and morale of the 25 million or so Americans who staff shift work schedules in industrial plants, transportation, emergency and security industries and provide these services for our society 24 hours a day, 365 days a year.

Mr. Chairman, the statistics are staggering. Imagine behind each of the five shift workers who testified in the first panel here today that the other shift workers in this country were lined up, we would have five lines each stretching 3,000 miles.

In other words, five lines of people would reach all the way from Washington back to California. That is the number of people who are coming and speaking to you through these representative shift workers appearing here today.

Biomedical research has only just begun to identify the source of the problems that arise and start to suggest where some possible solutions may lie. I am going to review for the committee very briefly what we now know, and what must be done to make sure this research is applied in practical settings.

I have brought a model of the human brain here to make an important point. Deep within our brains lie biological clocks, a legacy of our evolution on this rotating planet. This planet has been spinning once every 24 hours for the million or so years that human forms have been on the surface of this Earth, and because of that regular 24 hour spin, there has been a regular cycle, of light and dark, of cold at night, warm during the day, of food available at certain specific times of day, and predators on the prowl in the primitive world at certain times of day or night.

In response to this highly predictable periodicity, humans, like virtually all other plants and animals, have developed these internal circadian clocks. These internal timepieces beautifully equipped us for the environment of our origins. They time our sleep and wakefulness, our patterns of hormones in the blood, the temperature of our bodies, and virtually every aspect of our physiology and behavior.

These clocks enable animals—and for that matter, ourselves—to predict the time of day and night, to predict sunrise and sunset and to schedule our physiology and behavior accordingly. I suppose they are much like an automatic coffeemaker that is on a timer and switches on in advance of waking up in the morning, and starts warming up our bodies in advance of the time we rise. At the same time they start the release of various hormones in preparation for the day ahead. Thus when we are working a normal nine-to-five schedule, waking up at seven or eight in the morning, we wake relatively alert, as compared to the shift workers that you have been hearing from today.

It was only 10 years ago that the first circadian pacemaker was located, as I mentioned, in the human brain. It is a pair of tiny cluster of nerve cells half a millimeter in sizes, containing 10,000 or so densely packed cells which have a regular pulsatile beat with a period that approximates 24-hour period. Actually, it is about a 25-hour period in humans and a 23-hour period in mice for example. This regular beat of this pacemaker is reset each day so we keep synchronized to the light/dark cycle, using a special bundle of nerves that runs from the eyes, which detect light and dark, back into this pacemaker in the brain. This daily signal from our environment resets our biological clocks each day, so we correct from our spontaneous 25-hour cycle back to a 24 hours length every time the sun rises in the morning or we switch the lights on in the morning.

Mr. GORE. Doctor, if I may interrupt, what would be the advantage of a 25-hour clock that must be continually reset? Could you explain that?

Dr. MOORE-EDE. Yes. That is an excellent question and obviously is an important thing to think about. It is not only the periodicity that has to be the same as the earth's rotation but also the timing of the whole cycle is critical. It is no good if you have a regular cycle of waking up once every 24 hours but it is 4 o'clock in the afternoon, if, in fact, it is environmentally advantageous for you to wake up at dawn.

The fact that you have a steady natural drift of your biological cycle means that you can be more stably synchronized to the timing of a key environmental event such as dawn. Remember the early bird that catches the worm.

Mr. GORE. So presumably it would be related not just to the 24-hour cycle, but to the seasons, as well?

Dr. MOORE-EDE. That is right. This process enables a more flexible adaptation to the seasons. Actually, it is very hard to keep one clock that is exactly 24 hours sychronized by another. There is a lot of instability that occurs.

Mr. GORE. OK. Thank you.

Dr. MOORE-EDE. We now know in humans and in other primates, that there is a second clock. There is a second pacemaker, as Dr. Czeisler mentioned, which times the body temperature rhythm, and the rhythms of alertness and performance. We know that this clock is much harder to reset, and indeed, if you fly to Hawaii or to Europe and have to travel across several time zones, while the timing of your sleep adjusts relatively rapidly, the second clock which controls alertness takes much longer to adapt.

You can fool yourself because your sleep has adjusted to the new time zone, but your troughs and peaks of alertness won't have adjusted and they are the things that determine your performance on the job. This second pacemaker by the way is not yet identified. We do not know where it is in the brain, and this is one of the key questions that deserves major attention in terms of basic research in this field.

So smoothly do these internal clocks function, they might have remained just a biological curiosity were it not for the dramatic change that occurred in our temporal environment with Edison's invention of the light bulb and a reliable means of generating electrical power a hundred years ago. Although, the cavemen had fire, 19th century man had candles, oil lamps, and gas lights. Nothing could match the flick-of-switch convenience nor the brightness of electric light which can turn night into day at our whim.

This has caused a truly dramatic change in our society. You have to realize that up to about a hundred years ago, the pace of life was governed by daily rhythm from the crowing of a cock at dawn to putting the livestock to rest at night. Over 90 percent of our population in the year 1800 worked on the land, and even those in the cities worked from sunrise to sunset.

Edison's invention 100 years ago had two major effects. No. 1, it created the option to stay awake, a freedom that we now take for granted. We can now switch on the lights any time of day or night, and choose to work whenever we want to. But Edison's invention also created the requirement that increasing numbers of our population have to stay up and staff these facilities around the clock.

It has been the increasing automation in industry, particularly since the last war, and what is more, the increasing cost of capital investment that has meant that the monetary cost of staffing facilities around the clock has been absolutely trivial, when compared to the cost of constructing those facilities. If you can run something 24 hours a day, instead of 8 hours a day, 9 to 5, you are getting, essentially, three times greater utilization of the same facilities.

This factor is an enormous force driving us toward a 24-hour a day society. The problem is not a monetary one in the simplest of terms. The costs are human. There are staggering human costs to following this sort of schedule for which our bodies were not designed.

You have heard about the 25 million Americans that are on shift work, with at least 60 or 70 million people worldwide. You have heard from various people, not only airline pilots and nurses, but policemen, soldiers, and sailors, the secret service agents that guard our public figures, the computer operators, the truck drivers, the newspaper and TV and radio and entertainment personnel all having to work at night, at least part of the time.

Why does this matter? What is the importance? Can't we just learn to operate equally well day and night?

Well, it turns out that these biological clocks, that are so well designed for the 24-hour environment of our origins, were not built to adjust to the demands of modern society. Not being able to shift our clocks by much more than an hour or so a day in either direction was not a problem when the Wild West was won, when the covered wagons were trindled across the prairies. Even with the railroad, you never could travel more than one time zone, 1 hour of required shift per day. Similarly by ocean liner you never covered more than an hour per day.

So rapid shifts across time zones were never required in our society until the last 10 or 20 years. Since then staggering numbers of people have become involved.

We have not faced up to this challenge of modern society. We have not faced up to the fact that both insects and mice subjected to these schedules have a 5 to 20 percent decrease in life span. We have not faced up to the effects of fatigue, of gastrointestinal disturbances, increased cardiovascular risks, loss of alertness in shift workers. These medical problems are not confined to the aged.

They sap the energy and destroy the health of young and old alike, reducing the effectiveness of this Nation's work force and burdening our health care system.

There are many specific instances we could discuss, but I would particularly like to direct my attention to what sort of answers are possible at this time. Two major areas need attention.

First of all, we have to undertake more investigations into this very new area of research. I would like to emphasize that the clock that times the heartbeat, the pacemaker in the heart, was discovered in 1906, and there have now been 70-plus years of study on this phenomenon and we are much better off in understanding heart disease because of it; 70 years of basic research.

It is only 10 years ago that first circadian clock in the brain was discovered. We clearly need to learn more or probe more into how these clocks work. We need to learn how to reset them to the appropriate time of day.

There are now drugs which appear to be quite effective at resetting them, at least in preliminary studies. We need to identify the pacemakers in humans, characterize their properties.

As you have pointed out so clearly, there is also the need to apply this research, because although we are still like children riding bikes with training wheels, even the most simple findings that have been derived so far from this research can have enormous consequences.

Hence, there is a critical need to undertake applied research in this area and to actually apply these findings to real work settings.

Thank you.

[The prepared statement of Dr. Moore-Ede follows:]

TESTIMONY OF PROFESSOR MARTIN MOORE-EDE ON BIOLOGICAL RHYTHMS AND SHIFT WORK SCHEDULING BEFORE THE SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY, Washington DC
23 March 1983

Mr. Chairman and Members of the Committee:

I am Dr. Martin Moore-Ede, Associate Professor Physiology at the Harvard Medical School. I currently serve as Chairman of the International Commission on Circadian Rhythms and Sleep Physiology, and I am Chairman of the International Scientific Advisory Board of the Center for Design of Industrial Schedules.

The 24-hour-a-day society has swept the citizens of the industrialized world into a lifestyle for which our bodies were not designed. You have heard today testimony from workers who represent the 20 million or so Americans who staff shift work schedules in our industrial plants, transportation, emergency and security industries so that services are provided and industrial processes conducted continuously around-the-clock, 365 days per year. Their personal stories need no amplification to bring this point across.

The effects of this temporal revolution on modern man are enormous and biomedical research has only just begun to identify the source of the problems that arise, and suggest where possible solutions may lie. I will review for the Committee what we now know, and what must be done to make sure the applications of this research are fully developed for the benefit of the millions of individuals now living out of synch with the cycle of day and night.

Deep within our brains lies a legacy of our evolution on this rotating planet. Throughout the million years of human evolution, the earth has been rotating once every 24 hours, subjecting all its inhabitants to a highly predictable cycle of day and night. Not only was it relatively dark and cold at night, but predators were on the prowl and food was only available in the primitive world at highly predictable times of day or night.

In response to this highly predictable periodicity of our environment, humans, like virtually all other plants or animals, evolved internal circadian (approximately 24 hours) clocks. These internal timepieces beautifully equipped us for the environment of our origins. They time our sleep and wakefulness, the levels of hormones in the blood, the temperature of our bodies, and virtually every other aspect of our physiology and behavior. What these internal clocks are doing is that they enable animals and for that matter ourselves to predict the time of day and night, sunrise and sunset, and to schedule our behavior accordingly. I suppose they are much like an automatic coffee-maker that you switch on the night before and set the timer on. These clocks start warming up our body temperature in advance of the time we awaken in the morning; they also start the release of various hormones in preparation for the day ahead.

Just ten years ago the first circadian pacemaker was identified in the mammalian brain by Dr. Robert Moore, then at the University of California, San Diego. It is a pair of small 0.5mm clusters of nerve cells--comprising approximately 10,000 cells--sitting at the base of the hypothalamus. Two years ago, my colleagues and I reported that a comparable set of cells exists in the human brain (see Figure 1). It is called the suprachiasmatic nucleus because it sits just above the optic chiasm where the visual tracts from the eyes cross over as they enter the brain.

This circadian clock, located in the suprachiasmatic nuclei, generates its own periodicity independent of environmental time. If one places an animal, or for that matter a human subject, in a room with no time cues, where the lights are always on and there are no windows or clocks on the wall, the circadian rhythms will keep on measuring out day and night but with a periodicity all of their own. Mice, for example, will display a 23-hour spontaneous day length, drifting steadily out of synch with the 24-hour periodicity of rotation. Humans and squirrel monkeys in contrast free-run with a period of approximately 25 hours when isolated from environmental time, slipping steadily later each day with respect to the 24-hour time scale. To maintain synchrony in the outside world, our clocks must be reset each day an hour earlier for humans, or an hour later each day for mice.

It is the environmental light-dark cycle, the sun rising and setting, that provides the time cue that keeps plants, animals and man in the natural world synchronized with the earth's rotation. A special bundle of nerves, called the retino-hypothalamic tract, passes from the retinae of the eyes to the suprachiasmatic nuclei and resets the beat of that pacemaker so that it conforms with the 24-hour day.

In humans, and our primate cousins, we now know there is also a second pacemaker which is rather less easily reset by the alternation of light and dark in the environment. This pacemaker (its anatomical location is yet not precisely pinpointed) times the cycle of body temperature, plasma cortisol and, with it, the daily cycle of alertness and performance (Fig. 2: X = second pacemaker; Y = suprachiasmatic nucleus).

So smoothly do these internal clocks function, they might have remained just a biological curiosity were it not for a dramatic change that occurred in our temporal environment just 100 years ago. Thomas Edison's invention in 1882 of the light bulb and a reliable means of generating electrical power almost instantaneously, on an evolutionary time scale, freed the human race from the constraints of day and night. Although the cavemen had fire and nineteenth century man had candles, oil lamps, and gas lights, nothing could match the flick-of-switch convenience nor the brightness of electric light which could turn night into day.

This has caused a truly dramatic change in our society. Up until about 100 years ago, the pace of life was governed largely by a daily rhythm that went from the crowing of the cock at dawn to putting the livestock at rest at night. Over 90 percent of the population in 1800 worked on the land. And even those in the cities worked from sunrise to sunset. Edison's invention of electric light had two major effects. It created the option to stay awake at night, a freedom we take for granted, but it also created the requirement to stay awake among increasing numbers of our population. Right from the very first electric power station at Pearl Street in lower Manhattan, built by Edison in 1882 so he could switch on the lights on September 4th of that year, operators have been required to staff such facilities around the clock, 24 hours a day. The number of people required to stay up at night for such purposes has increased steadily, with two extra factors playing a role in this transformation of our society.

The increase in automation in industry, particularly since the last war, has made it increasingly possible to operate industrial processes continuously, 24 hours a day, 365 days a year. There is a large economic incentive, too. The expense of capital investment to build industrial plants is so enormous, and the monetary costs of staffing such facilities is so trivial in comparison, that increasingly the industrial world is forced to operate around the clock. The problem lies with the health of the worker, as I will discuss in a moment.

Along with this there has been, of course, the development of the jet airplane. We now have the capability to travel rapidly across time zones and suddenly confront our bodies with day when it ought to be night.

And so by this year, more than one in four of male workers, more than one in six of female workers, work rotating shifts--that is, they are switching alternately between day and nighttime work. Twenty million Americans, at least 60 million worldwide. And, of course, hundreds of millions crossing time zones each year. Who are these people? They're airline pilots; they're doctors. They're nurses, assembly line workers. Policemen, firemen. Soldiers, sailors. Secret service agents. Computer operators, truck drivers, newspaper, TV, radio, entertainment personnel. All having to work at night at least part of the time.

But why does this matter? What's the importance? Can't we just operate equally well, day and night? Well, it turns out that our biological clocks that were so well designed for the 24 hour environment of our origins were not built to adjust to the demands of modern society and modern schedules. In fact, our internal clocks can only shift by about an hour or so each day. This was no problem for travel in olden times -- if you think about the Wild West and the covered wagons trundling across the prairies, there was no way that they could cover even a fraction of a time zone in a day. And even by train or by ocean liner, there was no way you could cover more than a time zone, an hour of required shift per day.

The human race has not yet faced up to challenges caused by the widespread requirement for shift work around the clock. Insects and mice subjected to a weekly shift of the day-night cycle show 5 to 20 percent decreases in their life span. No studies have yet been conducted in humans to investigate the long-term effects of extended exposure to shift work, but the fatigue, gastrointestinal disturbances, increased cardiovascular risk, and loss of alertness among shift workers have significant immediate costs for their health and their productivity. Shift workers also face considerable stress in their social and family life.

Sleep disruption and fatigue in shift workers have consequences even for those who do not work at night. The Federal Aviation Administration rules on rest time and duty time do not take into account the 24-hour sleep-wake cycle. A pilot can be scheduled to flip-flop between daytime and nighttime flying, as long as he has a few hours off after each episode of flying. Such erratic schedules, coupled with shifts across time zones, contribute significantly to pilot fatigue, which is increasingly being recognized as an important cause of accidents. Errors by shift workers in other industries may have even more widespread consequences. While a direct relationship cannot be proved, the Three Mile Island nuclear power plant accident occurred at 4:00 A.M. with a crew that had just rotated onto the night schedule. This is at the minimum point of the daily cycle of alertness, when errors of omission and slowness in responding to warning signals are most likely to occur.

What is the answer? We cannot assume that human body functions are like a machine. It does not run equally well day and night. The body is only well equipped to function in the environment of our origins, from sunrise to sunset. But we do have the ability to take over control over our schedules and control of the lighting in the world around us. It is the regular world of our origins that we have to preserve in the increasing temporal chaos around us. Particular attention, of course, has to be paid to the shift worker. We have to design schedules that are suitable for them, that enable them to adjust their times of rest and sleep. Society can no longer dispense with services provided 24 hours a day, and we must adjust and learn to cope with this demand.

To achieve this goal, we have to probe more into how these clocks work. Learn how to reset them to the appropriate time of day. Identify the pacemakers in humans and characterize their properties so that optimal schedules can be done. The strides forward in this field of research in the past 5-10 years have been significant, but considerable support will be needed to foster the research that will enable man to thrive in the round-the-clock society he has created.

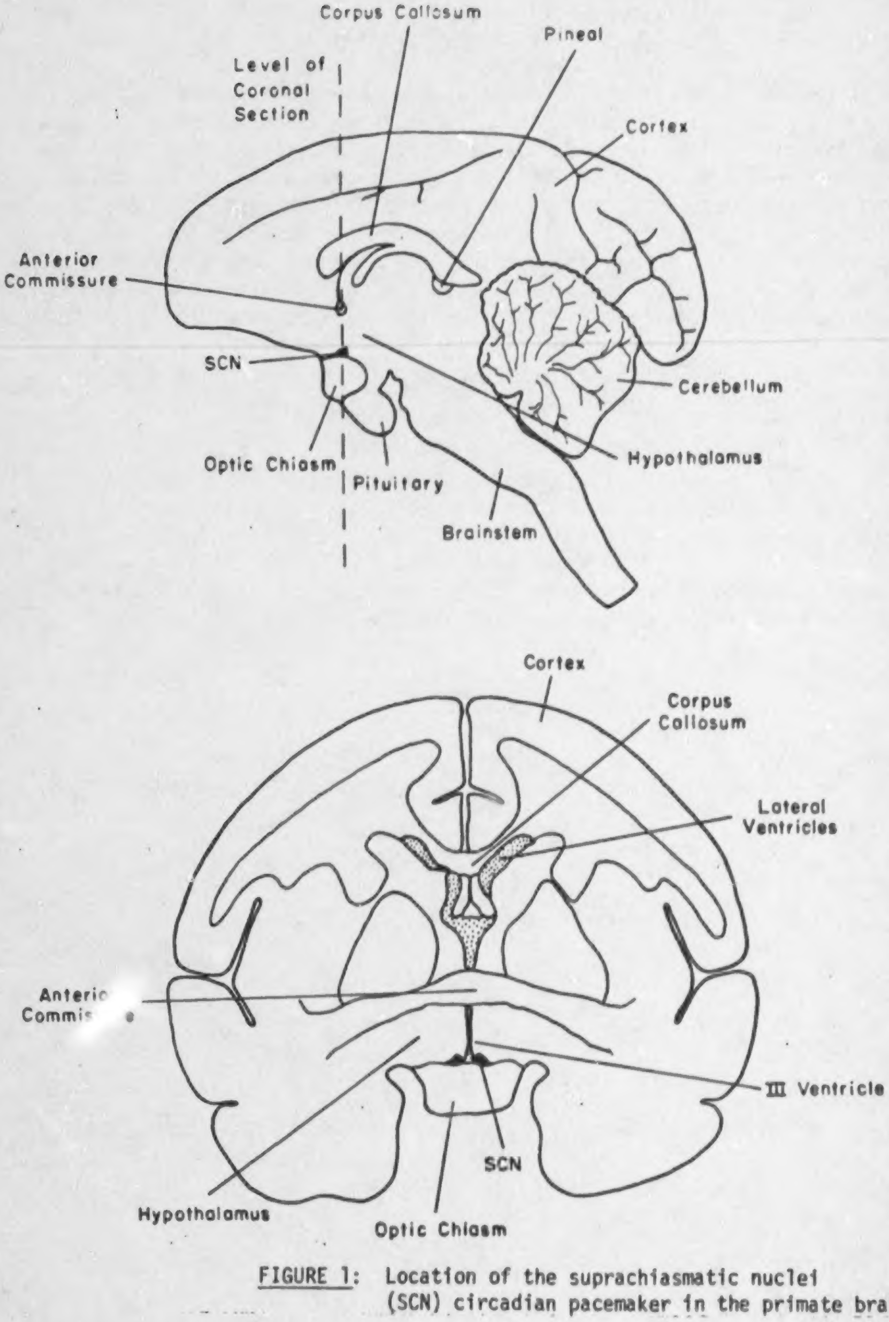
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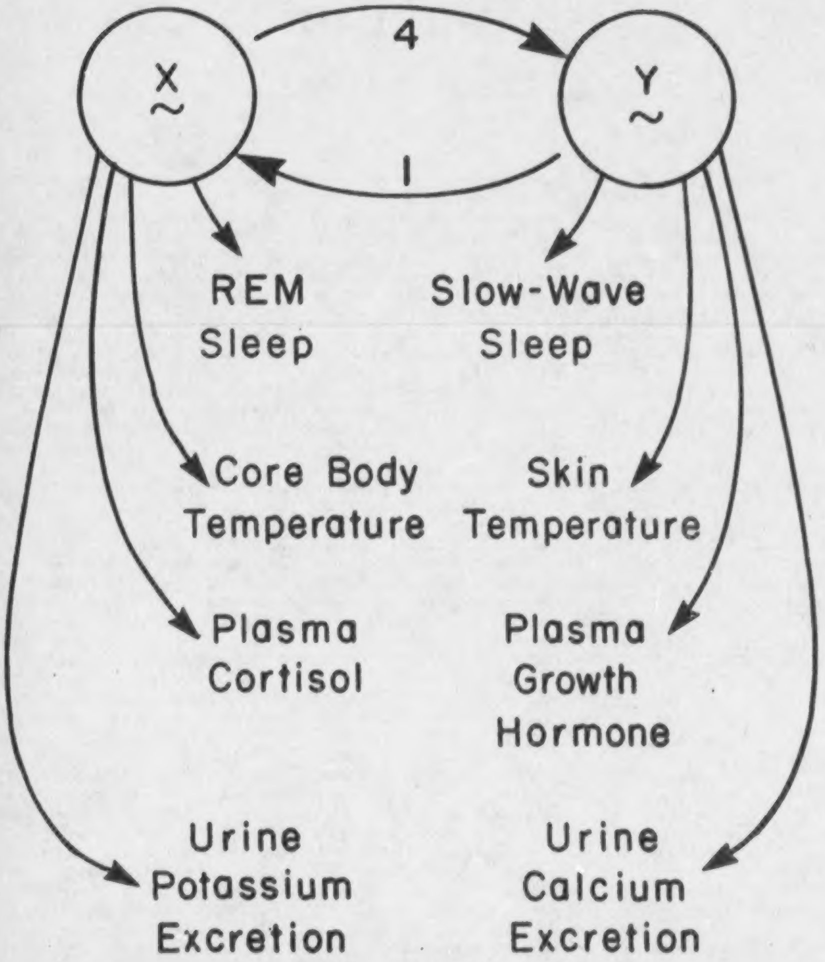
FIGURE 1: Location of the suprachiasmatic nuclei (SCN) circadian pacemaker in the primate brain.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REM Sleep
Slow-Wave Sleep
Core Body Temperature
Skin Temperature
Plasma Cortisol
Plasma Growth Hormone
Urine Potassium Excretion
Urine Calcium Excretion

Fig. 2 The two groups of rhythms appear to be driven by separate pacemakers. Pacemaker X drives the rhythms of REM sleep, core body temperature, plasma cortisol concentration, and urinary potassium excretion. Pacemaker Y drives the rest-activity cycle and the rhythms of slow-wave sleep, skin temperature, plasma growth hormone concentration, and urinary calcium excretion. The coupling force exerted by X on Y is approximately four times greater than that of Y on X. (Copyright 1982 by Moore-Ede, Sulzman, and Fuller.)

# Sleeping As the World Turns

*The Monday morning blues is just another sign that we are ruled by internal timekeepers*

by Martin C. Moore-Ede

The tendency for some organisms to be active at night and others during the day would have been apparent to humans in their earliest contemplations of the temporal order of nature. Written observations on the subject go back to the fourth century B.C. when Androsthenes, the traveling scribe on the marches of Alexander the Great, reported that the tamarind tree, known at that time primarily for its laxative fruit, opened its leaves during the day and closed them at night. Other early descriptions of the periodic behavior patterns of plants and animals are scattered throughout the world's literature, most notably Linnaeus's remarkable documentation, in the eighteenth century, of the daily opening and closing times of a multitude of flowers. Linnaeus even devised a "clock" by cultivating, in the appropriate areas of his garden, flowers that predictably opened and closed their petals at different times. By inspecting his garden, Linnaeus could tell the time—a prospect apparently greeted with some concern by the clockmakers of his day!

In these early writings there is no sign that anybody interpreted the observed daily rhythms as anything but a passive response of organisms to a cyclic environment. This apparently reasonable assumption was not tested until Jean Jacques d'Ortous de Mairan, an astronomer by training, conducted a critical experiment in 1729. In a brief communication to the Royal Academy of Sciences in Paris, he reported on his studies of the leaf movements of a "sensitive" heliotropic plant—one that bends or turns in response to light. This plant was probably *Mimosa pudica*, which unfolds its leaves and pedicels during the day and folds them at night. When de Mairan moved the plant to his cellar, where sunlight could not reach it, he found that it still opened its leaves during the day and folded them for the entire night. Thus the persistence of circadian rhythms in the absence of environmental time cues was first demonstrated. De Mairan recognized the broad implications of his findings for plants and animals and even for ailing humans confined in sick rooms where they could not see the regular progression of day and night. Nevertheless, he finished his brief report with the comment that the progress of experimental science was slow, and he did not have the time to explore this phenomenon further.

Many years passed before the significance of de Mairan's findings was appreciated. Internally generated rhythmic behavior, synchronized to the twenty-four-hour period of the earth's rotation, is not just a biological curiosity. The major function of internal clocks (the circadian timing system) is to measure time and thus allow organisms to anticipate the occurrence of environmental events correlated with day-night cycles. The temperature and illumination of the environment, the availability of food, and the activity of predators all vary over the course of the twenty-four-hour day, and an organism's survival often depends on successfully predicting and preparing for such events.

Appreciation of the timekeeping role of circadian rhythms can be traced back to the beginning of this century. In 1910 a Swiss physician, August Forel, reported that as he and his family were taking breakfast on the terrace of his summer home in the Alps, a few worker bees from a hive about 130 yards distant arrived to sample some marmalade on the table. After a few days, he observed that the bees often appeared on the terrace just before breakfast was served, as if they knew it was time for the food to arrive. Finally, finding it impossible to eat outdoors, the family moved indoors, only to notice that for several days afterward the bees continued to arrive at the terrace table exactly at breakfast time. Because they appeared only at that time of day, Forel suggested that the bees might possess a *Zeitgedächtnis*—a memory for time.

That organisms can truly coordinate their behavior with the time of day was demonstrated in 1929 by German scientist Karl von Frisch and his graduate student Ingeborg Beling. Beling's technique was to mark bees individually and then offer them sugar water at an artificial feeding place for several days—always at the same hour. Then one day no food was placed in the dish and the time of arrival of each bee was observed. In almost all cases, the bees arrived at or near the training time. Even conducting such experiments in the constant conditions of a salt mine, 600 feet below the surface of the earth, did not alter the bees' capacity for timekeeping. Evidence that an internal circadian system was responsible was provided by the finding that the bees could be trained only when food was placed at intervals close to twenty-four hours. If food was presented at nineteen-hour or forty-eight-hour intervals, the bees showed no capability for predicting the pattern.

In 1955, Max Renner of the Institute of Zoology in Munich conducted a definitive experiment to test whether bees were sensing something in their environment that the experimenters had missed. He had identical, windowless laboratories constructed in Paris and in New York City. In the French laboratory he trained forty bees to collect sugar water between 8:15 and 10:15 P.M., then transported the bees overnight to the New York laboratory. The next day the bees again arrived at the feeding table at 8:15 to 10:15 P.M., French time. These experiments showed that neither cosmic rays nor any other unscreened environmental cues could be transmitting temporal information to the bees.

The bees' internal circadian timing system enables them to avoid wasting energy in futile visits to flowers that, following a circadian schedule themselves, offer their nectar or pollen only at restricted times of day. Once bees have identified a flower with nectar available at a given time, they can return each day at the appropriate time, whether or not the sun is shining or other temporal cues are present.

Of particular value in studying circadian clocks is the isolation technique originated by de Mairan in his demonstration that circadian rhythms persist even when an organism is isolated from time cues. By taking an organism out of its natural milieu and placing it in a chamber where the levels of light, temperature, food, and sound are kept constant, an experimenter can largely eliminate the influence of environmental factors that ordinarily obscure internal circadian rhythms. Thus the cycles that emerge under these constant conditions reflect more directly the behavior of the internal clock (or clocks) under study.

Beginning in the 1920s Erwin Bünning in Germany laid the foundations for much of our current understanding of the properties of circadian systems. For example, he demonstrated that plants and insects raised in constant conditions display circadian rhythms. These rhythms are "free running," that is, they have a periodicity of close to, but not exactly, twenty-four hours, so that in the absence of time cues from the environment they gradually deviate from solar time. By crossing strains of plants with different internal periods, he went on to show that the free-running period is genetically inherited. Bünning was the first to recognize that circadian clocks also enable organisms to detect seasonal changes in day length, and he pointed out the evolutionary advantages of this ability. For example, an animal attuned to day length can start getting ready for reproduction in advance of the long days of summer. A large number of investigators have since extensively documented the properties of circadian clocks and demonstrated their ubiquity in organisms ranging from single-celled algae to humans.

Since the 1950s Colin Pittendrigh, first at Princeton and then at Stanford University, has done much to convince biologists of the importance of circadian clocks. In 1954 he published the first of a series of elegant papers demonstrating that the time of day that the fruit fly (*Drosophila*) emerges from its pupal casing is controlled by a circadian clock that is little influenced by variations in environmental temperature. Although most metabolic processes speed up considerably with increases in body temperature, the period of circadian clocks does not. This independence is essential if a circadian clock is to be an effective timekeeping device. Pittendrigh's work also demonstrated that circadian rhythms are not learned phenomena, as Beling and her associates had implied by their use of the word *Zeitgedächtnis*. *Drosophila* pupae raised in constant conditions did not need to be exposed to a twenty-four-hour light–dark cycle to show a circadian rhythm: a single brief flash of light once in the organism's lifetime was all that was necessary to trigger it. Furthermore, separate strains of the flies could be bred, each with distinct rhythmic properties.

Despite the growing evidence of the internal nature of the circadian timekeeping processes, some researchers still believed circadian rhythms might be the product of undiscovered environmental

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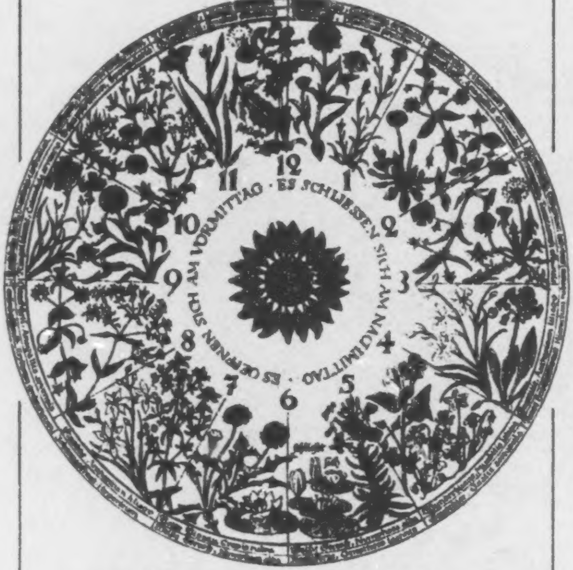
A Flower Clock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ES SCHLIESSEN SICH AM NACHMITTAG · ES OEFFNEN SICH AM VORMITTAG

... as devised in 1745 by Linnaeus, "so that even in overcast weather, out in an open field, a person would be able to tell the time as precisely as if he had a clock with him."

*An artist's diagram of a clock, published in Germany, depicts the flowers Linnaeus suggested could be used to tell time. On the left-hand side, representing the hours from 6:00 A.M. to noon, are flowers that open in the morning (except for one, the common sowthistle, which closes). At right are shown flowers that close during the afternoon, between noon and 6:00 P.M. (except evening primrose, which opens). Two plants are illustrated for each hour and identified in the border by their names in German and (sometimes outdated) Latin. Starting at six and going clockwise, the common English names of the morning plants are: pink hawksbeard, white water lily; Saint Bernard's lily, Saint Johnswort; scarlet pimpernel, centaury; carthusian pink, field marigold; ice plant, spurry; tiger lily, common sowthistle. The afternoon flowers are: field marigold, Childing pink; mouse-ear hawkweed, scarlet pimpernel; chicory, common dandelion; Saint Bernard's lily, red hawkweed; four-o'clock, European wood sorrel; white water lily, evening primrose.*

oscillations. Frank Brown, emeritus professor of biology at Northwestern University, has been one of the last proponents of this concept. He has demonstrated that organisms are responsive to weak electromagnetic fields in their environment. Although he has shown that such fields could potentially transmit circadian information, he has not proved that they actually do so.

A number of studies have attempted to rule out the effects of unrecognized cues that might be produced by the earth's rotation. For example, in an experiment conducted at the South Pole, Karl Hamner, a botanist at UCLA, showed that circadian rhythms in hamsters, fruit flies, and *Neurospora* (a fungus with a prominent circadian rhythm of spore growth) persisted even when these organisms were placed on a table that rotated counter to the earth's rotation. Nevertheless, skeptics could still argue that some unrecognized twenty-four-hour cue could be operating. For example, the electrical generator for the South Pole station might be on a twenty-four-hour timer and hence create periodic electromagnetic fields. An obvious environment in which to settle this question is outer space, where organisms can be isolated from twenty-four-hour cues. Up to now, however, animals on space missions (such as the monkey on NASA's Biosatellite III) have been maintained on a twenty-four-hour light-dark cycle in the capsule. In conjunction with two other researchers—Frank Sulzman and Charles Fuller—I plan to put claims about environmental cues to the test next year using NASA's space shuttle. We will send up tubes containing *Neurospora*, keeping them in constant conditions well away from the earth's daily rhythms.

Apart from such isolation experiments, extensive data show a genetic basis for circadian rhythms. Using X-rays or chemicals, mutant organisms with a wide range of periods can be produced. Furthermore, each species has a characteristic free-running period and each individual within a species has its own unique periodicity. The accumulating evidence is rendering untenable the theory that circadian rhythms are externally determined.

It is only twenty years since the first de Mairan-type experiments were conducted with humans. In the early 1960s, Jürgen Aschoff and Rütger Wever built a windowless apartment in the basement of a Munich hospital; it had no clocks, no access to radio or TV, and no other cues relating to the time of day. The subjects had no contacts with the experimenters and they ate their meals and slept whenever they wished. At the same time, an independent experiment was being conducted by a French group headed by Michel Siffre, director of the French Institute of Speleology in Nice. Siffre lived alone in an underground cavern in the French Alps. Deep within the mountain, with no natural light, he too was isolated from the external world and had no knowledge of the time of day.

In both these experiments, human circadian rhythms were shown to have a periodicity somewhat longer than twenty-four hours, typically about twenty-five. Hence, the peaks and troughs of the subjects' rhythms shifted one hour later each day so that, over the course of three or four weeks, the time of sleep progressed all the way around the clock and they lost an entire day. On reentry into the regular world, subjects were surprised to find that it was

Friday, not Thursday, or Monday, not Sunday.

The tendency for the human sleep–wake cycle to drift later each day by about an hour is a matter of common experience. During weekends, freed from the tyranny of alarm clocks or school or work schedules, most of us stay up later and sleep later. The result is that by Monday morning, our internal circadian systems have shifted two or three hours out of sync with solar time. Hence, when we get up on Monday morning at 7:00 and feel terrible, our body time may actually be 4:00 A.M.—thus accounting for the Monday morning blues.

Shortly after initiating the pioneering studies in Munich, Jürgen Aschoff was appointed director of the Max Planck Institute for Behavioral Physiology, located in Erling-Andechs, a delightful village in the foothills of the Bavarian Alps. With Rütger Wever, Aschoff constructed an elaborate two-apartment isolation facility in an underground bunker built into a hillside. The bunker contained electromagnetic screening to prevent any influence of periodic environmental electromagnetic radiation. Double-compartment doors with locks were built through which food and other materials could be passed without the experimenter and subject ever seeing each other. Each bunker was equipped with its own kitchen and bathroom, enabling volunteers to live independently for weeks on end. Since the 1960s, more than 200 subjects have been studied in this facility, either alone or in small groups, typically for periods of three to four weeks. In each case, free-running circadian rhythms have been observed in a host of physiological and behavioral functions, including rest and activity, body temperature, plasma hormone levels, reaction time, vigilance, and mental computation skill. Each rhythm reaches a peak at one characteristic time of day and a trough at another.

One of the most important findings to come out of this facility is that the circadian rhythms of activity and body temperature can on occasion run independently of each other. For example, a subject might spontaneously adopt a thirty-three-hour rest–activity cycle, perhaps sleeping for thirteen hours at a stretch and being awake for twenty hours, but at the same time his body temperature rhythm would keep a periodicity close to twenty-five hours. Not only does each rhythm deviate from solar time but the rhythms also deviate from each other. The only possible explanation is that at least two separate clocks exist in the human circadian timing system.

To study these phenomena in more detail, and to understand more about the control of sleep and the implications for clinical medicine, Charles Czeisler, Elliot Weitzman, Richard Kronauer, and I established a human isolation facility on the top floor of Montefiore Hospital in New York City. Windows were boarded up and clocks, radios, and TVs were removed, creating apartments similar to those built by the German investigators. However, we did not make elaborate arrangements to exclude noise from aircraft or from street traffic or to exclude electromagnetic radiation.

As we suspected, the human subjects in this facility showed free-running periods of approximately twenty-five hours, similar to those reported from the underground caves of the French investigators and the shielded bunkers of the Germans. Our subjects, who have ranged from twenty to seventy years of age, have lived by themselves in this facility for up to six months at a time. They could choose the time of going to bed and of arising, as well as when they wanted to eat. They were not isolated from contact with the experimenters and technicians, however. The technicians, whenever entering the apartment, would take care to remove their watches, to be freshly shaved (if a man), and to provide no clues or indications of the time of day or even which day it was. When greeted with "Good morning," they were trained to respond accordingly. The subjects could order their breakfast, lunch, or dinner whenever they wished. It would be prepared outside and brought in whether it was 10:00 P.M. for breakfast or 5:00 A.M. for lunch. To avoid the subject's deducing the time of day by which technician was on duty, we randomly computed the schedules so that no technician's shift was consistent either in duration or time of day.

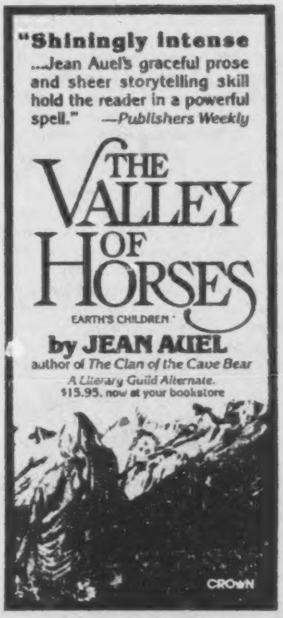
As the German group had seen, internal desynchronization of the sleep–wake cycle and the body temperature rhythm occurred in a number of our first subjects, who spent just one month in temporal isolation. When subjects remained in the facility longer (up to six months), virtually *all* eventually showed internal desynchronization. This suggests that whatever coupling there might be between the two clocks, it is not sufficient to maintain internal synchrony for extended periods of time in the absence of a periodic environment.

From our study of internally desynchronized subjects, we learned that it was the point in the body temperature rhythm when the subjects went to bed that determined the duration of sleep. Subjects who went to bed as their body temperature was falling (as we do in the normal world) would sleep for seven or eight hours. If subjects went to bed when their body temperature was at its maximum, however, they would sleep for fourteen or sixteen hours. This relationship remains true even in the outside world, provided that one has been awake for a regular day length of at least fourteen hours. People who have been on a regular schedule of sleeping from eleven at night to seven in the morning and then stay up for most of the night will only sleep for a few hours if they go to bed at 5:00 A.M., when body temperature is low. However, if they stay up until midafternoon, they will then be able to sleep continuously for sixteen hours or so until the next morning, barring outside disturbances.

The effect of the circadian clocks on sleep patterns is extremely powerful: the length of time you will sleep is not determined by how long you have been awake. In 1966, a seventeen-year-old boy in San Diego, attempting to set a record, stayed awake for eleven days and nights (264 hours). When he finally went to bed he only slept fourteen hours (which was determined by the circadian time he chose to go to bed), and he slept eight hours a night thereafter.

Our circadian rhythms of sleep and wakefulness evolved in synchrony with the regular day–night cycles of our rotating planet. Only in the last few decades, a mere instant on the evolutionary time scale, have the jet plane and the availability of services around the clock dislodged us from the temporal niche in which we evolved (see *Natural History*, September 1982). After traveling across multiple time zones or rotating between day, evening, and night shifts at an industrial plant, a person's body time will be out of sync with the schedule of the outside world. It takes several days before circadian rhythms can readjust to a new environmental time.

Both animal and human studies have enabled us to understand why it takes so long for people to adjust after changing time zones. Circadian clocks can only be shifted from their twenty-five-hour periodicity by an hour or two each day in either direction. This range safely encompasses the normal period of the earth's rotation, but it provides little additional margin for shifting, especially in the advance (eastward) direction. Adjustment on average is faster in a westward direction (delaying one's circadian rhythms with respect to environmental time) because this represents less deviation from the internal twenty-five-hour cycle (recall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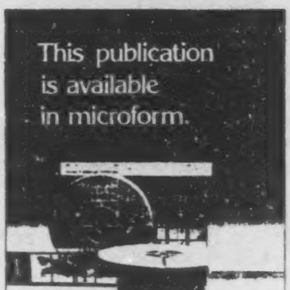
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that subjects in isolation experiments lengthen each day by about an hour without even realizing it). Klein and his colleagues in West Germany have shown that in a westbound trip across six time zones, a person's rhythms of psychomotor performance take four days to adjust, whereas the same rhythms take an average of eight to ten days to resynchronize after eastbound flights. (Because there is more than one clock, some rhythms take longer to adjust than others, and so the time for full readjustment of the circadian system may be even longer after such travel.)

Because of the limits to resetting circadian clocks it is not possible to live on an eighteen-hour or a thirty-hour day–night cycle and keep the entire circadian system in step. Yet such schedules are in use today. The Stockholm police work a shift system that starts four hours earlier each day and, hence, live on a twenty-hour day–night schedule. Similarly, the crews of the atomic submarines of the U.S. Navy, which cruise under the ocean for a couple of months at a stretch, are maintained on an eighteen-hour day–night cycle, operating three shifts of only six hours in length. Crew members have twelve hours off duty between work shifts, including six hours' sleep time. Although there is some choice in scheduling the sleep time, individuals on such naval watch schedules have considerable problems with insomnia, emotional disturbance, and impaired coordination, and their sleep is highly fragmented compared with that of personnel on shore-based installations. Perhaps the best indicator of the difficulty is the high turnover of enlisted men in U.S. submarine crews—as high as 33 to 50 percent per voyage—and the small number of men who undertake more than two or three of the ninety-day submarine missions. There would be considerable advantage to adopting a twenty-four-hour work–rest schedule for the whole crew, not just for the officers as is the current practice. In this way, the men could function optimally and the dropout rate might be lower.

As I discussed in my previous article, among the major issues for the twentieth-century work force is the problem of staffing critical industrial, security, and emergency services around the clock. The information now available on the circadian timing system permits the design of shift-work schedules so that they least disrupt workers' internal rhythms. A number of different approaches have been used. The first, and perhaps the most obvious, is to place workers on straight shifts so they do not rotate their time of duty. However, staffing the night shift is often difficult and even when on the night shift, workers usually revert to daytime activity on their weekends or days off. Another strategy, particularly favored in Europe, is to place workers on rapidly rotating schedules whereby they stay on any one shift for only one or two days at a time. In this way, it is reasoned, workers will not have time to adapt to a new sleep cycle, but instead will continue their usual twenty-four-hour periodicity. Of course, workers who draw the night shift may have a significant dip in performance between 3:00 and 5:00 A.M.

Alan Reinberg in France has pioneered another strategy that takes account of individual differences in the ability to adjust after a shift in sleep and work times. Hiring individuals who are most tolerant of schedule changes can minimize the effects of rotating shift work. But major legal issues arise whenever an employer tries to select workers according to their susceptibility to agents or factors in the workplace. My colleagues Charles Czeisler (Harvard) and Richard Coleman (Stanford) and I favor a fourth approach. Through the Center for Design of Industrial Schedules, a Boston-based nonprofit service organization, we have placed industrial shift workers on schedules that rotate less frequently. In one case, the workers in question had previously changed shifts every week; under the new arrangement, they only changed shifts every three weeks. Thus they had more time to reestablish their sleep and performance rhythms after each change in shift. We also changed the direction of shift rotation so that it conformed to the natural tendency of the sleep–wake cycle to drift to later hours.

Until now most shift-work schedules in industry have been a matter of local practice or industry tradition and have not taken into account biological factors. The new information on the mechanisms of the circadian timing system makes it possible to devise more rational approaches. I am currently chairing an International Scientific Advisory Board that is reviewing and evaluating governmental regulations and health policies in situations where the work schedule may relate to public safety, such as airline pilot schedules. The time has come to solve a problem that affects so many people.

*Martin C. Moore-Ede, professor in the Department of Physiology and Biophysics of The Harvard Medical School, is coauthor of* The Clocks That Time Us: Physiology of the Circadian Timing System, *published by Harvard University Press.*

Mr. Gore. Thank you, very much.

Dr. Wehr, we have a quorum call on the floor. We will have a brief recess for about 6 or 7 minutes and then come back and hear your testimony.

[Recess.]

Mr. Gore. The subcommittee will come back to order. We were about to hear from Dr. Thomas Wehr, Acting Chief of the Clinical Psychology Branch at NIMH. Dr. Wehr, welcome.

[The biographical sketch of Dr. Wehr follows:]

**DEPARTMENT OF HEALTH & HUMAN SERVICES**

Public Health Service

National Institutes of Health
Bethesda, Maryland 20205

## BIOGRAPHICAL INFORMATION

## THOMAS A. WEHR, M.D.

Thomas A. Wehr, M.D. is a psychiatrist who specializes in research and treatment of depression and sleep disorders. His main scientific interest has been the role of biological clocks in health and disease.

Since 1973, Dr. Wehr has conducted clinical and basic research in the Intramural Research Program of the National Institute of Mental Health, where he is the Acting Chief of the Clinical Psychobiology Branch. He attended the University of Louisville Medical School and Yale University for his undergraduate and psychiatric residency training. Dr. Wehr has published sixty scientific papers in his field and in 1982 received the Anna-Monika Foundation Award for Research in Depression. He is a member of several scientific organizations, including the American Psychiatric Association, International Society for Chronobiology, and International Scientific Advisory Board of the Center for Design of Industrial Schedules. He has taught courses and given numerous lectures on the topics of depression, sleep disorders and biological rhythms, and serves as a reviewer for several scientific journals.

Dr. Wehr's research has led to the development of electronic instruments that are capable of continuously monitoring the sleep-wake cycle and activity rhythms in ambulatory patients and healthy persons. His research has also shown how shifts in the timing of sleeping and waking or light-dark schedules can alter the clinical condition of depressed patients. Together with his colleagues, Dr. Wehr has also found that bright environmental light is capable of regulating certain hormones in healthy persons and the level of mood and energy in certain manic-depressive patients.

Dr. WEHR. Thank you, Mr. Chairman. I am pleased to have the opportunity to testify on the topic of biological rhythms in shift work scheduling.

I should say at the outset that my field of research has not been specifically shift work, but it has been looking at the impact of shifts and alterations in sleep and other environmental factors on certain illnesses.

As we have already heard, a wide range of behaviors and functions of the human body exhibit daily cycles of variation. For example, we are alert and efficient at certain times of the day and drowsy and inefficient at others.

These daily changes do not simply occur because of decisions we make or because of external demands of the environment or work schedule. They are genetically programed and are driven by a biological clock in the brain.

As we have heard, this human biological clock is a 25-hour clock, and it will generate a 25-hour cycle of waking and sleeping in the absence of any external input.

Normally a brain mechanism, which we have already heard about, resets the 25-hour rhythm of the human biological clock so that it remains synchronized with the external 24-hour day-night cycle.

This mechanism through its connection with the eyes detects daily changes in environmental lighting conditions, such as dawn and dusk, that function as time cues that reset the biological clock.

In animals, the clock-resetting function of light has been clearly demonstrated. In humans, the importance of environmental light in the regulation of the human biological clock is still a matter under investigation.

For example, our group at the National Institute of Mental Health has found that rather bright light can stop the secretion or production of a hormone by a gland, the pineal gland, in the center of the brain.

This effect of light on this brain gland and its hormones is controlled by the same nerve circuits that control the human biological clock. I would like to emphasize that ordinary, artificial light, such as you might have in your home or in an ordinary office environment, does not affect this system.

It is bright artificial light, and it was really, I think, a very key finding that artificial light approaching the intensity of sunlight as seen through a window, for example, on a clear day, is necessary to activate some of these mechanisms.

This would be the kind of light, for example, that is used by television crews or in certain industrial settings. Sometimes I have wondered when I have watched the evening news about the long-term effects of the television lights suppressing the activity of this particular gland and also, possibly, changing the timing of the sleep-wake cycle.

These findings raise two possibilities. First, bright environmental light can disturb the timing of biological clocks that control the sleep-wake behavior and performance efficiency that we have heard about.

That is a negative effect. On the other hand, bright artificial light could also be used deliberately to correct the timing of biological clocks or help them adapt to shift or travel schedules, and I believe that we have reached the stage in basic research where one or two more years of work will probably produce enough information about the effect of light on the human biological clock to construct practical guidelines for the intelligent regulation of environmental lighting conditions in the workplace.

Mr. **Gore**. Does bright light affect the setting of both biological clocks or just one?

Dr. **Wehr**. Well, the end result is that it affects the setting of both clocks. There may be a lag or kind of a communication from one of those clocks to the other, but the end result is that you could presumably control both clocks. But I think experimentally, we don't have enough information about details that that question raises. We need more experience with exposing normal human subjects to light pulses given at different times of day and these kinds of isolation experiments that you have heard about.

We are currently conducting such experiments at our research work at the National Institute of Mental Health.

Mr. **Gore**. Thank you.

Dr. **Wehr**. We have already heard that the human biological clock takes several days to reset its timing after shifts and sleep and work schedules and that it is easier to shift in the delay or slowing down direction than in speeding up direction.

I think that there is a real possibility that, for example, artificial light or, another important possibility is that drugs which mimic the effects of artificial light could be used to hasten this process of resetting.

There is currently some information from animal research that specific drugs can actually activate these pathways in the brain that ordinarily are responding to light and can reset the clocks.

So one can imagine, for example, in a few years, perhaps, that not only light could be used, but some sort of system of specifically timed pharmacological agents could be used to rapidly adjust people to new schedules.

Now, another point I wanted to make is that the behavior of the human biological clock, and specifically its manifestations in the sleep-wake cycle, can now be easily and continuously measured with small electronic instruments, one of which I am actually wearing, which is very lightweight—with some more development it could be made even smaller—which continuously registers physicial activity.

Through this kind of measurement, one can detect changes in levels of energy, which may vary according to time of day in different schedules, and also one can indirectly measure the sleep-wake cycle, the timing of sleeping and waking and the continuity of sleep or, in some cases if sleep is interrupted, it can be detected by this instrument.

This type of instrument could be cheaply manufactured and applied on a large scale to the study of the effects of shift work on human physiology and performance in the work place.

We have used them in a very limited setting with patients involved in certain types of experiments involving the human biological clock.

Now, what do we know about the impact of shifting sleep and work schedules on health or on the course of pre-existing diseases. So far we have very little specific epidemiological evidence to answer this question. We do have some data from experimental studies of the effects of shifts on patients with certain disorders.

I am really citing these as examples, and one can imagine that looking at other illnesses, one might find other interesting and important information about the effects of shifts.

But I am going to focus on two or three disorders with which I am familiar. First of all, interrupting or shifting sleep schedules can cause approximately 50 percent of patients with medical depression immediately to switch out of depression into a normal state, which is a desirable effect or into a manic state, which is often an undesirable effect.

This, by the way, occurs within hours after shifting the sleep or depriving a person of sleep. Usually, it persists only for a day or two, although in some cases it may persist for weeks.

Depression produces sadness, decreases energy, impairs concentration, and decreases ability to function. Mania increases energy, impulsiveness, emotional instability, and impairs judgment.

As an example, I cite the case of a physician whose oncall schedule required him to remain awake all night every third night that he was working. This is a very common, almost standard shift schedule in many hospitals throughout the country.

Every third day after the sleepless night, the doctor switched from depressive to a manic state, then returned to a depressed state after a night's sleep. This cycle of mania and depression every 3 days continued for about a month and a half.

Eventually these mood shifts were controlled with pyschiatric drugs, and this doctor was able to function normally. This example shows how shift work can interact with preexisting illness to produce behavior changes in well-trained persons who ordinarily function at a high level.

In our experience, changing sleep schedules, therefore, can cause and correct mood disturbances. Second, changes in the timing and duration of exposure to sunlight or bright, artificial light can switch patients with seasonal mood disorders into depression, normal states, or mania, depending on the schedule of light exposure.

Again, we feel that this response depends partly on an interaction of environmental, bright environmental light, with the timing mechanism that is involved in the circadian clock which you have heard previously also helps to detect and control seasonal rhythms.

There is a group of patients who become depressed every winter, starting in November and typically comes out of that depression and go into either a normal state or a manic state in the spring, usually about March.

These changes can be controlled with external, bright, artificial light on different schedules.

Last, shifting or erratic work schedules can induce a specific type of sleep disorder in predisposed persons. Perhaps 10 percent of the patients who come to sleep disorders clinics have a syndrome characterized by an inability to fall asleep until very late at night and a difficulty arising in the morning.

Because of the mismatch between their internal sleep program and the demands of social and work schedules, they are chronically deprived of sleep and do not function well. These patients have a biological clock disorder.

The clock can be reset to a later time, but not to an earlier time. It is kind of an exaggeration of what occurs normally, except that it is much more difficult for these people to shift earlier than later than would be true for the average person.

They can be treated by rotating their sleep period progressively later each day until they are shifted the long way around to an appropriate evening bedtime. Such persons adapt poorly to shift work.

For example, a stewardess first developed the delayed sleep phase syndrome while working on an erratic flight schedule.

Each of these examples illustrates how changes in the timing of sleep and lighting can cause exacerbations of preexisting illnesses or can be used to treat them.

Some of these illnesses have behavioral symptoms that affect performance and judgment. I would conclude that, first of all, sleeping, waking, and performance efficiency are not simply controlled by environmental demands or the individual's decisions or wishes, they are largely controlled by an internal program governed by a biological clock, which is somewhat slow to adjust to sudden changes in schedules.

Second, shifts in work, sleep, and lighting schedules appear to be capable of both causing and treating mood and sleep disorders. These findings are based on longitudinal studies of groups of patients. There is no epidemiological evidence on the frequency of these disorders among shift workers. There is little data on the effects of shifts on other diseases.

Instrumentation now exists which could be applied on a large scale to the study of the effects of shift work on human physiology and performance.

Finally, it is likely that bright environmental light plays a role in the regulation of hormones and in the timing of biological clocks that affect mood and performance. In principal, light can both cause and correct biological clock disturbances, depending on how it is used.

Within 1 to 2 years, answers may be obtained from basic research that will provide a basis for the rational use of environmental light in complex work environments.

Thank you.

[The prepared statement of Dr. Wehr follows:]

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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STATEMENT

BY

THOMAS A. WEHR, M.D.

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BEFORE

THE

INVESTIGATIONS AND OVERSIGHT SUBCOMMITTEE OF THE

HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

MARCH 23, 1983

Mr. Chairman and Members of the Subcommittee:

I am pleased to have the opportunity to testify on the topic of biological rhythms and shift work scheduling. Specifically my testimony will deal with biological clocks and their implications for human health.

## I. Effect of environmental conditions on the human biological clock.

A wide range of behaviors and functions of the human body exhibit daily cycles of variation. For example, we are alert and efficient at certain times of day and drowsy and inefficient at others. These daily changes do not simply occur because of decisions we make or because of external demands of the environment or work schedule. They are genetically programmed and are driven by a biological clock in the brain.

The human biological clock is a 25 hour clock. In the absence of any external input, it will generate a 25 hour daily cycle of waking and sleeping. Normally a brain mechanism resets the 25 hour rhythm of the human biological clock so that it remains synchronized with the external 24 hour day-night cycle. This mechanism through its connection to the eyes detects daily changes in environmental lighting conditions (dawn and dusk) that function as time cues that reset the biological clock.

In animals, the clock-resetting function of light is clear. In humans, the importance of environmental light in the regulation of human biological clocks is still being investigated. For example, our group at the National Institute of Mental Health (NIMH) has found that rather bright light can stop the nighttime production of hormones by a gland (the pineal) in the center of the brain. This effect of light is controlled by the same nerve circuits that control the human biological clock. Ordinary artificial light has little effect. Bright artificial light such as that used by television crews or in certain industrial settings has a powerful effect.

These findings raise two possibilities: (1) bright environmental light can disturb the timing of biological clocks that control sleep-waking behavior and performance efficiency; (2) bright light can be used deliberately to correct the timing of biological clocks or help them adapt to shift or travel schedules. We have reached a stage in basic research where one or two more years of work will probably produce enough information to construct practical guidelines for the intelligent regulation of environmental lighting conditions in the work place.

The human biological clock takes several days to reset its timing after shifts in sleep and work schedules (this lag time is the basis of jet lag). It is easier to shift the clock later than earlier because of its slow 25 hour rhythm. After schedule shifts, there is a temporary mismatch between the person's readiness for efficient error-free performance and external demands of the work schedule. For example, workers rotating to the night shift or troops flown halfway around the world find that they are being asked to function at a time when their biological clock dictates that they are least alert and most error-prone. Schedule shifts that take into account the slow rate of resetting and the direction of resetting of the biological clock may lead to better performance and more worker satisfaction. Furthermore, basic research soon may show how bright artificial light can be used to accelerate the rate of resetting of the clock.

The behavior of the human biological clock and the sleep-wake cycle can now be easily and continuously measured with small, electronic instruments recently developed by the National Institute of Mental Health. These instruments could be cheaply manufactured and applied on a large scale to the study of the effects of shift-work on human physiology and performance.

## II. Resetting the biological clock in health and disease.

What do we know about the impact of shifting sleep and work schedules on health or on the course of pre-existing diseases? So far, we have very little epidemiological evidence to answer this question. We do have some data from experimental studies of the effects of shifts on patients with certain disorders:

(1) interrupting or shifting sleep schedules can cause 50% of patients with medical depression immediately to switch out of depression into a normal state (a desirable effect) or into mania (an undesirable effect). Depression produces sadness, decreases energy, impairs concentration and decreases ability to function. Mania increases energy, impulsiveness, emotional instability, and impairs judgment. As an example, I cite the case of a physician whose on-call schedule required him to remain awake all night every third night. Each third day after the sleepless night the doctor switched from a depressive to a manic state, then returned to a depressed state after a night's sleep. Eventually his mood shifts were controlled with psychiatric drugs. This example shows how shift work can interact with preexisting illness to produce behavior changes in well trained persons who ordinarily function at a high level. In our experience changing sleep schedules can both cause and correct mood disorders.

(2) changes in the timing and duration of exposure to sunlight or bright artificial light can switch patients with seasonal mood disorders into depression, normal states or mania, depending on the schedule of light exposure.

(3) shifting or erratic work schedules can induce a specific type of sleep disorder in predisposed persons. 10-20% of patients who come to sleep disorders clinics have a syndrome characterized by inability to fall asleep until very late at night and difficulty arising in the morning. Because of the mismatch between their internal sleep program and the demands of social and work schedules, they are chronically deprived of sleep and do not function well. These patients have a biological clock disorder. The clock can be reset to a later time but not to an earlier time. They can be treated by rotating their sleep period progressively later each day until they are shifted the long way around to an appropriate evening bedtime. Such persons adapt poorly to shift work. For example, a stewardess first developed the delayed sleep phase syndrome while working on an erratic flight schedule.

Each of these examples illustrates how changes in sleep and lighting schedules can (1) cause exacerbations of pre-existing illnesses or (2) be used to treat them. Some of these illnesses have behavioral symptoms that affect performance and judgment.

## III. Conclusions

1. Sleeping, waking, and performance efficiency are not simply controlled by environmental demands or the individual's decisions or wishes, but are

largely controlled by an internal program governed by a biological clock, which is somewhat slow to adjust to sudden changes in schedules. Therefore, shift work leads to a temporary mismatch between work demands and performance efficiency.

2. Shifts in work, sleep, and lighting schedules appear to be capable of both causing and treating mood and sleep disorders. These findings are based on longitudinal studies of groups of patients. There is no epidemiological evidence on the frequency of these disorders among shift workers; there is little data on the effects of shifts on other diseases.

3. Instrumentation now exists which could be applied on a large scale to the study of the effects of shift work on human physiology and performance.

4. It is likely that bright environmental light plays a role in the regulation of hormones and the timing of biological clocks that affect mood and performance. In principle, light can both cause and correct biological clock disturbances, depending on how it is used. Within one to two years, answers may be obtained from basic research that will provide a basis for the rational use of environmental light in complex work environments.

Mr. **Gore**. Thank you very much. Please forgive me if I ask you what that is on your right wrist.

Dr. **Wehr**. This is an example of the type of instrument that I was describing. This device essentially measures whether or not my wrist is moving, but by doing that and recording that on a regular basis, it can be used to detect how active I am, and also when I am awake and when I am asleep.

With this device it is possible to essentially follow the sleep-wake cycle, for example, indefinitely in a person who is wearing it because it is relatively unobtrusive in its present form and it only has to be read out.

The data, in other words, is obtained from the instrument every 10 days, so that it is readily usable, for example, in studies of shift work.

Mr. **Gore**. Dr. Moore-Ede, let me ask you a couple of questions about the science of this. When the human body clocks are reset, the image I have is similar to the instrument—an odometer in an automobile. Maybe it is not called that, but for a while when I was trying to figure out how many miles per gallon I was getting, every time I would fill up with gasoline, I would punch a button and it would push the odometer back to zero; it would reset it that way. It doesn't work that way; does it?

Dr. **Moore-Ede**. No; in fact, the odometer you can set all the way back to zero. You cannot set these body clocks back by more than about an hour in either direction from their natural 25-hour cycle.

Mr. **Gore**. In other words, when you reset your body clock, you can't reset it more than an hour different from the point on the cycle that it was at the previous day?

Dr. **Moore-Ede**. Yes; you can't set it more than about an hour, hour and a half different from 25 hours. That is, that you can bring it to a 23-and-a-half-hour day on that particular day or maybe a 26-and-a-half-hour day in the other direction.

But you can't change in any 1 day by more than that. That means if you now fly across six time zones and you take a vacation in Paris, for example, it would take the best part of 6 days for those body clocks to be resynchronized. They are slow to adjust; they were not built for rapid shifts.

There was never an evolutionary reason why they had to be built to cope with the zone shifts. They were not designed for the sort of schedules that we now live.

Mr. **Gore**. So if you are working in a factory and you go through a shift change of 8 hours and try to adjust your sleep-wakefulness cycle by that much, it will take you a minimum of 8 days to reset it; is that right?

Dr. **Moore-Ede**. That is basically the problem. The problem on a weekly rotating schedule, is that you are just about resynchronized by the end of that week, even if you are going in the optimum direction.

The problem is you then shift all over again, so you never ever catch up. The scientific data matches with the subjective reaction of the workers that Dr. Czeisler and I studied. They reported that it took the best part of a week for their sleep by their own account to be reset, bearing in mind all they can evaluate is their sleep. They really don't have a feeling of their performance and we weren't looking at their temperature rhythm which probably might take even longer to adjust.

Mr. **Gore**. Now, the graphs that Dr. Czeisler showed on the two body clocks, the two main body clocks, I guess you would have to say, indicated that the flexibility of the sleep-wakefulness clock was much greater than the body temperature alertness clock.

Am I to conclude from that that the length of time that you can reset the sleep-wakefulness clock is greater than for the other one?

Dr. **Moore-Ede**. Yes; it appears to be. Indeed, you can put people on a 28-hour day schedule, and you can demonstrate that providing the time cues, such as light and the dark cues, are strong enough, the sleep-wake cycle will march along. You can constrain it on that 28-hour day.

But what you can't trap is the body temperature rhythm and the pacemaker, the clock that times it. So you can just split the whole system apart in that experiment. One clock marches along with the time schedule you are imposing and the other can not keep up with it.

Mr. **Gore**. You wanted to make a comment, Dr. Wehr.

Dr. **Wehr**. Yes; I just wanted to add that in experimental animals who are placed on different schedules, that to some extent their capacity to adapt to different schedules is a function of the intensity of light to which they are exposed on the light/dark cycle that is used.

There is some, at present, unpublished data in humans suggesting that there may be a similar response in humans, so that just being a little future oriented here, it may be that the rate of resetting could be affected simply by using brighter intensities of light in the environment at the appropriate time, but that is obviously something that needs to be studied.

Mr. **Gore**. I used to raise chickens, and we had two chicken houses each with 5,000 chickens. We doubled the production of eggs by having the sun rise twice instead of once each day.

In the middle of the night the bright lights would come on and they would trot over to the conveyor belt and lay their eggs.

Dr. **Moore-Ede**. That is an illustration of a clock that you can synchronize to a faster periodicity. Now, I don't know if you ever tried trying to get three eggs per day, but there will be a limit to that.

In other words, the timing system which controls egg laying is rather more labile and can be driven to a wider range than the one that is timing such things as the body temperature rhythm here.

I would like to just make one brief set of remarks to place everything that we have heard in perspective. There is an important question of research strategy here. You can decide you want to cure cancer and you can throw all sorts of money at such a problem, but if the underlying basic research if not at a sufficiently advanced stage you will spend a lot of money and not get very far.

In contrast, I would like to submit that in the area of biological rhythm and shift work scheduling, the basic research so close to being applicable that just a little supportive nudge to this whole area could be enormously fruitful. There are a considerable number of potential answers that are just sitting below the surface and a concerted effort to support such research could be very profitable at this time.

Mr. GORE. Do we know anything about the effect, Dr. Wehr, of caffeine or alcohol on the resetting mechanism?

Dr. WEHR. Yes; there is some evidence that if caffeine, properly timed, could reset biological clocks. There is now fairly clear evidence in animal studies, and there are some human studies—in fact, I think that you will be hearing some testimony about that from——

Mr. GORE. Tomorrow.

Dr. WEHR. Yes. Alcohol in certain animals does appear to slow down the biological clock. This merely raises the question, I think, since I am not aware of any human data, that possibly excessive use of alcohol might feed into this problem of tending to want to drift later, could exacerbate it.

There are other drugs, we are beginning to learn, which also affect the resetting process of the clock. I think in terms of development of pharmacological agents, that some of them show a lot of promise.

There are some which act rather specifically on these neural pathways that go from the eye to the biological clock, which ultimately could have applications in humans.

Mr. GORE. Now, many jet travelers have found it easier to adjust to a westward time zone change than to an eastern time zone change, yet the FAA in papers published in 1966 came to the opposite conclusion.

In your opinion, was that study simply an error?

Dr. MOORE-EDE. Let me address that. The studies you are mentioning were done at a time before the various components of the circadian timing system were clearly recognized and before there was any understanding that there were two clocks.

Unfortunately people have studied what happens to the sleep-wake cycle during travel across time zones without realizing that they are looking at the adjustment of a complex system. There are many studies more recently conducted which have been done rather more carefully. Certainly our clinical experience with patients is demonstrating very clearly that it is the shift in the westward direction, the delay shift, which is much easier to accomplish than the eastward shift.

Mr. GORE. That is a gentle and elegant yes.

Dr. MOORE-EDE. Yes to the question whether there are problems; yes.

Mr. GORE. Whether the study was in error?

Dr. MOORE-EDE. Yes.

Mr. GORE. Yes. All right. Now, am I correct in stating that there are two major body clocks and that there may be several others that we don't yet know much about?

Dr. MOORE-EDE. Yes. The data so far that rather clearly points to there being two major pacemakers, although there are other subsidiary oscillators in the body, come from nonhuman primates and from man. The data are less conclusive from other species, although this is a matter of some scientific debate. Providing we are talking about primates and man, the evidence is pretty suggestive that we have two major systems. They drive various peripheral oscillators, which are normally kept in sync, by this central pair of key clocks.

Mr. GORE. On the applications of research that has already come to fruition, I am not wrong, am I, in thinking that it would make a great deal of sense for the employers of those 25 million Americans who have regular shift rotations to redesign their shift rotations so as to have them correspond more nearly with circadian rhythms and, thereby, minimize the disruption of their employees' body clocks?

Is that a sort of sensible conclusion?

Dr. MOORE-EDE. In general, it is, yes. The problem, however, is more complex when it comes to the appreciation of this research. Although the general circadian principles, should be applied, there are many features, such as the operational requirements of the particular facility, that are vastly different. The staffing needs, the level of training and so forth, all vary. There are also issues to do with worker preferences, their lifestyle and their lives outside work which have major influences. So that we have found it absolutely essential that we take into account those features, as well as the biologic principles.

So there is no one schedule for which one can say, "OK, here it is, plug it into place." It won't work. Because actually it is only going to be successful if it involves the workers and it involves management. As a result it is an enormously complex process to put one of these things actually into action.

We have proven it is possible to do so, however. Furthermore, there was one feature which may not have come out clearly. One of the essential components of this whole exercise was a process of educating the workers on how to take advantage of the schedule.

We can send a tractor down to Brazil, but if we don't send an instruction manual with it, the machine as soon as it breaks down or as soon as it runs out of gas will lie there idle in the field.

Indeed, I think one of the most important things we accomplished was worker training sessions which enabled them to learn various techniques which facilitate their adjustment to the schedule. I would just like to leave you with the picture that there are various components to this process of applying the key scientific principles.

Mr. GORE. And other factors have to be——

Dr. MOORE-EDE. They all have to be juggled. A huge jigsaw puzzle is what it comes down to.

Mr. GORE. But that having been said, it is quite true, is it not, that a great many million Americans are working on a shift rotation that does not reflect worker preference or essential characteristics of the industry involved, but have rather come about because of the arbitrary kinds of factors such as the factors that led the potash plant to adopt the schedule they did. Where those shift rotations are being used, it certainly makes a lot of sense to adjust them to take into account circadian rhythms, bearing in mind that these other factors have to be accounted for.

It would seem to me that worker preference would change in many cases when and if employees became more familiar with what the health and physical, psychological implications of different rhythms were.

Dr. **Moore-Ede**. That is correct. We have isolated for you today two specific features out of the science which are applicable. There are quite a few others which we believe deserve further study and evaluation, and we believe there are better schedules that could be designed using these other factors. As yet we have just published this one report. So I don't want to leave the impression that this is the magic cure, which will work on all occasions.

There are half a dozen other principles which have not yet been tested, but which we believe that at least some of them may work. We heard about the slow drift experiment. We tried to move them over gradually. That didn't work.

But there are others, some of which also may be very valuable.

Mr. **Gore**. Let me ask you what those are, if you can do it very briefly. To recap briefly, the two that we know are valuable and applicable are leaving enough time for adaptation to the new shift and, second, advancing the shift forward by fewer hours rather than a greater number of hours.

What are the other half dozen, just briefly?

Dr. **Moore-Ede**. Well, just to give you a flavor of them, you have heard from Dr. Wehr about the influence of light intensity, the possibility of developing techniques related to application of light intensity at certain phases of the cycle.

You have heard also briefly mentioned, I think, from both of us that there are now certain drugs which are turning out to be effective in the laboratory at resetting the timing of these pacemakers and which potentially may be useful as a new class of sleeping medications.

In other words, current sleeping medications basically do not address this problem. Sleeping pills have not been shown to reset the timing of these pacemakers, and yet there may be other very specific types of agents that could help people with problems associated with adjusting to their work schedule.

So there is a pharmacological type of approach, which is going to be important to evaluate. There are a whole number of questions to do with the timing of meals and meal schedules and how those are handled, which have not been addressed in these sorts of settings.

Yet, we know that certain components of meals and possibly even certain very specific components of diet may act as synchronizers to these clocks. There is also the whole issue of social interaction between individuals which appears to have some synchronizing influence, but has not been properly explored.

Mr. **Gore**. What was that last one?

Dr. **Moore-Ede**. Groups of people studied in temporary isolation facilities tend to synchronize each other. There is some social interaction that is complex, maybe pheromonal. We don't know.

Mr. **Gore**. Now, when you say pheromonal, those are the tiny, microscopic particles that are picked up by the palate, through their smell.

Dr. **Moore-Ede**. I want you to understand that this is speculation. But I am saying there is something going on that is synchronizing individuals, one with another that is apparently independent of lighting and other things in the environment.

Mr. **Gore**. Well, that phenomenon is at work with menstrual cycles, is it not?

Dr. **Moore-Ede**. There is some evidence of the synchronization of the menstrual cycles of women. These are just giving a flavor of a few things that are possibily useful. Some may require more research than others.

Some, in fact, are testable in real life settings at this time. I think we need to get more data directly on what is happening to these shift workers. With the sort of device that Dr. Wehr has here, it is critical to do studies on shift workers so that we can actually understand how their biological clocks are behaving under the schedules they work.

Mr. **Gore**. Dr. Wehr, do you think that there are is a good deal or a quantifiable amount of mental illness that could be attributable to the experience undergone by these 25 million shift workers that have their circadian clocks all scrambled up on a regular basis?

Dr. **Wehr**. The only evidence that we have on that is coming really from another perspective, which is what happens if you take a person with a known disposition to have, let's say, manic/depressive illness or a depressive illness or certain types of sleep disorders and subject that person to various kinds of shifts or other sorts of interruptions of sleep.

In that case we know, as I mentioned, about 50 percent of those people will experience sometimes very dramatic behavioral changes. Depending on the kind of shift that is involved, they can be sustained, those changes can be sustained.

We really don't have the kind of epidemiological evidence coming, you know, from the other direction. That is, how many of these people are working in shift work and, you know, what evidence is there that they are, in fact, developing manic or depressive episodes or certain types of sleep disorders in the work environment.

That is needed. That kind of epidemiological survey is needed, I think.

Mr. **Gore**. Back on the social cues or pheromonal phenomena, it is true, is it not, that yawns are contagious?

Dr. **Moore-Ede**. Mr. Chairman, I am not an expert in such matters.

Mr. **Gore**. I don't mean it as a totaly light question. I mean, I think that that is true, isn't it, if somebody yawns?

Dr. **Moore-Ede**. As a layman on this particular subject, I have seen sufficient reason to believe that that may be true, yes.

Mr. **Gore**. I won't tell you how many times that phenomena has occurred in hearings before this subcommittee.

Well, we have an exciting day tomorrow to followup this good start. I want to thank you all for rounding out the day here. I find this a fascinating subject and it is clear that more research is needed.

We will attend to that matter in our consideration of the research budgets that come before the Science and Technology Committee and we will likely have a subcommittee report which will offer some recommendations in that area after we consult among ourselves.

It is clear to me that we need a much broader application in our society of these scientific discoveries.

The hearings tomorrow will convene at 9:30 in the morning in this building in room 2325. I would like to, again, thank all of our witnesses today and a special thanks to our last panel.

Thank you very much.

[Whereupon, at 2:20 p.m., the subcommittee recessed, to reconvene the following day, Thursday, March 24, 1983, at 9:30 a.m.]

# BIOLOGICAL CLOCKS AND SHIFT WORK SCHEDULING

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## THURSDAY, MARCH 24, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Investigations and Oversight,
*Washington, D.C.*

The subcommittee met, pursuant to call, at 9:45 a.m., in room 2325, Rayburn House Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

Mr. Gore. The subcommittee will come to order.

I would like to welcome our witnesses and guests. I would also like to apologize for the brief delay in getting started this morning.

At yesterday's session we heard workers from a wide variety of occupations testify that shift work was highly detrimental to their physical, mental, and social well-being, loss of sleep, irritability, fatigue, gastrointestinal disorders, inability to spend useful and productive hours with family and friends, a common litany of disorders and problems that prompted one witness to say he would quit his job rather than go back to his old schedule of shift rotation.

Even more importantly we learned that people in critical professions—airline pilots, nurses, policemen, nuclear powerplant operators—often found it difficult to perform at full efficiency because of the physiological and mental problems arising from the stress of rotating or irregular work schedules.

Thus, in some circumstances one could almost say that public health and safety was at risk because of poorly conceived, traditional shift designs.

What the scientists told us yesterday is that the traditional 7-day rotating shift used by most industries is incompatible with our natural body clocks because it does not allow sufficient time for them to adjust to a new shift. Roughly half the time the 7-day schedule rotates in the wrong direction; that is, against the natural inclination of our body clocks to run with a longer than 24-hour cycle.

The typical 7-day rotating shift thus violates two simple principles that have developed from circadian rhythm research: One, shifts should rotate to later, not earlier times with each rotation; and two, as much time as possible should be allowed between rotations so that people can adjust.

If these simple rules are followed, we were told, there would be less chance that a worker would have to perform a critical function when his alertness, reaction time and body functions were at the low point of their normal daily cycle.

We look forward to hearing from today's witnesses about the factors that determine how shift work schedules are designed and practiced, and about new public and private sector initiatives that attempt to address from a biological rhythms perspective the many serious problems posed by poorly designed shift rotation systems.

We also look forward with interest to testimony from the Federal Aviation Administration and the Nuclear Regulatory Commission regarding their view of the problems and potential solutions identified in these hearings.

As a followup to these hearings, the committee plans to organize the findings and make them publicly available. The committee anticipates that the information brought together here will be of use to labor, management, and public officials in their efforts to help improve health and safety protection for workers and the public, to promote greater jobs satisfaction, and to improve productivity and economic growth.

Mr. **Gore**. We are delighted to have in our first panel, Mr. John L. Zalusky, economist, with the AFL-CIO, and Dr. Richard Ward, professor at the Department of Industrial Engineering at West Virginia University in Morgantown.

Mr. Zalusky, I am delighted to ask you to lead off. Without objection the entire text of the prepared statements will be included in full in the record. We invite you to proceed with your presentation.

## STATEMENTS OF JOHN L. ZALUSKY, ECONOMIST, DEPARTMENT OF ECONOMIC RESEARCH, AFL-CIO, AND RICHARD E. WARD, ASSOCIATE PROFESSOR OF INDUSTRIAL ENGINEERING, WEST VIRGINIA UNIVERSITY, MORGANTOWN, W. VA.

Mr. **Zalusky**. We appreciate the opportunity of being here, Mr. Chairman.

Your interest in shift work demonstrates the sensitivity to this problem that we certainly appreciate in the labor movement.

The scientific evidence available today clearly indicates that shift work causes stress and has a variety of physiological and sociological consequences. It also indicates that these effects increase with age. The problem is aggravated as the work force is growing older and normal retirement has just recently been extended from age 65 to 67. With this in mind, it is time to begin looking at ways of coping with shift work as an economic, sociological, and psychological problem.

There tends to be about four reasons for shift work. One is there are some types of occupations that simply require shift work: Police, fire, utilities. There are others that are continuous processes: Chemical plants and steel mills. There is work that is maintained on a shift work basis for the public convenience: Night shopping, fast food services, and that sort of thing.

There is work that is performed to maximize capital recovery, which tends to be the area we feel is going to be growing. There is a need to utilize the capital investment to avoid rapid obsolescence of it and to cover the high cost when labor costs are relatively less expensive.

About 16 percent of the work force is on some form of shift work other than the normal day work schedule, according to data from the current population survey taken by the Bureau of Labor Statistics in 1981. That proportion has remained quite stable since 1973, when they began asking these questions.

That in itself is rather interesting because the composition of our industrial complex has changed in the last few years. This movement to shift work in particular industries is demonstrated by an analysis by the Bureau of Labor Statistics industrial wage surveys.

In 1951, 32 percent of the productive, nonsupervisory work force in petroleum refining were employed on rotating shifts. In 1965, the number increased slightly to 33 percent. By 1981, 50 percent were on rotating shifts.

The synthetic fiber industry had 42 percent of its work force on rotating shifts in 1948, 45 percent in 1966, and 60 percent in 1981. Other industry studies show a substantial use of shift work in gas and electric utilities, with 7 percent of its work force on the second shift and 5 percent on the third. Shipbuilding has about 25 percent on the second shift and 10 percent on the third.

The computer industry, one of our growth industries, had about 45 percent of its professional technical staff on shift work in 1978. This varies significantly from geographic location, with the northeast region, Nassau-Suffolk County, N.Y. to the Houston, Tex., area. The Nassau-Suffolk County area had approximately 20 percent of its computer work force on the second shift and 20 percent on the third, while the Houston area had 10 percent on the second shift and less than 10 percent on the third shift.

Unions have been dealing with shift work for some time, and today most collective bargaining agreements provide special provisions dealing with shift work. Generally, these contract provisions provide for shift work selection based on length of service for the employer. About 83 percent provide for shift work premium pay, and some provide for shorter hours, about 16 percent, on the second and third shifts.

I have attached a paper I did some time ago on the subject. The machinists have reported their own experience, as a union, with the shift work problems. Most of their research was based on their own practical experience over time, and that is attached in Appendix II.

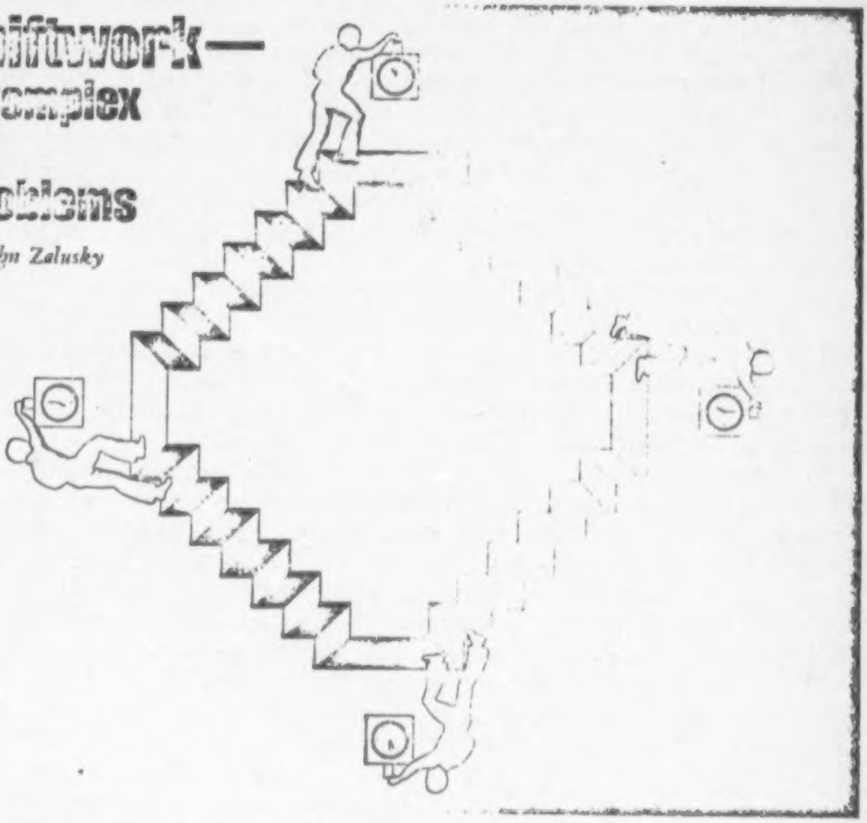
Mr. GORE. Without objection we will include your article in the record of these hearings.

[The material follows:]

APPENDIX I

# Shiftwork— A Complex Of Problems

*by John Zalusky*



**In recent years** the quality of work life and what is often considered a related subject, "alternate work schedules," have received growing attention. Alternate work schedules are usually presented as an alternative to the 8 a.m. to 5 p.m. work day. A good deal of attention has been given to the 10-hour, four-day week and even the 12-hour, three-day week, splitting full-time jobs into part-time jobs, with flexible starting and quitting times. Yet the most common and historically oldest alternate work schedule, shift work, has received comparatively little notice.

The most common definition of shift work is a regularly scheduled work week of hours outside the daytime hours—beginning around 7 a.m. and ending before 6 p.m. Work day schedules during these "normal" working hours become known as the day shift when shift work is used. Two other common shifts are the evening shift, ending around midnight, and the night shift, from midnight until the beginning of the day shift the following day.

Additionally, workers are often assigned to "swing shifts," which fill in the gaps between the rotating shifts where the plant operates continuously. Shift assignments normally occur through fixed shifts, oscillating shifts, or rotating shifts.

**Shift work exists** and grows for a variety of reasons. Some jobs require shift work by their very nature; for example, police work and continuous process industries like steel where it is inordinately expensive to start up and shut down. Other reasons are to make maximum use of capital investment in equipment and plant. Other shift work is caused by the needs of the marketplace, like all-night shopping, and the newest factor, energy costs. Utility companies are now experimenting with lower rates after most of the community has gone to bed, and companies are moving production workers to night shifts to save on electricity costs.

*JOHN ZALUSKY is an economist in the AFL-CIO Department of Research.*

**Worldwide, it is estimated** that the number of workers who work shifts has doubled in the last 20 years and that night workers are now 8 to 15 percent of the workforce.

But shift work is much more common in the United States—reflecting the industrial size and scope of a nation big enough to include almost all industrial combinations. The U.S. Department of Labor estimated for 1974-75 that 28 percent of the workers in manufacturing in metropolitan areas worked on late shifts. Most shift workers worked the day shift, 19 percent the evening shift and 7 percent the night shift. That 28 percent for 1974-75 is a peak, up from 22 percent in 1959-60, 24 percent in 1964-65 and 25 percent in 1967-68, the last measure before 1974-75.

Differences in how industries use shift work show that it's concentrated in continuous process operations and those with high capital investments. For instance, synthetic textile mills have 53 percent shift work, pulp paper mills 46, industrial chemicals 35, petroleum refining 32, glass containers 53, basic iron and steel 48, motor vehicle parts 35, meat packing 11, men's and boys' shirts 1, wood furniture 5, fabricated structural steel 18, machine tools and dies 13 and office machines 17.

In its 1978 household survey representing all nonagricultural wage and salary workers the BLS found 11 percent on late shifts, 84 percent working days, and another 5 percent on other shifts. This data does not deal with rotating shifts because the question asked the sample was what hours were worked last week. Thus when we look at all workers we find a substantial proportion of the U.S. workforce on shift work.

**Most of the early research** on shift work comes from European studies. Research began in the United States during World War II, and much of it dealt with flight crews. It wasn't until the last 10 years that research spread to American workers in hospitals, factories and the many places where workers have hours other than 8 a.m. to 5 p.m. Study of U.S. shift work involves consideration of its physical, social and psychological effects on workers.

## The Shift Vocabulary

- Fixed shift assignments are permanent assignments to the night shift, evening shift, or day shift until the worker has acquired sufficient rights and an opportunity to move to another shift. In this situation, workers change shifts individually rather than as a group on a regular schedule.
- Oscillating shifts are a form of continuous coverage where workers move from day shift, to night shift, and back to day shift, while another team shifts the opposite way of a regular schedule. This type of scheduling provides maximum day shift coverage while maintaining coverage 24 hours a day. Oscillating shifts of this general type are usually found in hospitals or related situations.
- Rotating shifts are normally used when continuous coverage is necessary. Their design and operation are as different as human imagination has been able to construct.

Currently, Europeans have shown much more concern about shift work than Americans. In fact, the secretariat of the nine-nation European Common Market is now calling for the enactment of legislation reducing the working time of shift workers. It also insures the right of older workers and long-term shift workers to return to day work.

In France, the government has recently issued a decree prohibiting the introduction of new shift systems unless there is a 14-hour break between the firms' operating hours. Employers can be exempted, but must show good cause and report the views of the union. If the employer is permitted to have shift work on a permanent basis, facilities for hot meals and comfortable seating are required. Also, workers must have physical examinations to determine whether or not they are suited for shift work.

The Dutch are considering a law to phase out the usual four-shift system and go to a five-shift system with more time off for shift workers, and an increase in shift premiums to maintain earnings. The Dutch unions are planning to seek a work week which has 33.6 hours for each shift.

The Swedes have reduced the work week for shift workers from 40 hours to 35.14 hours on continuous shifts and 38.3 for those on two-shift systems.

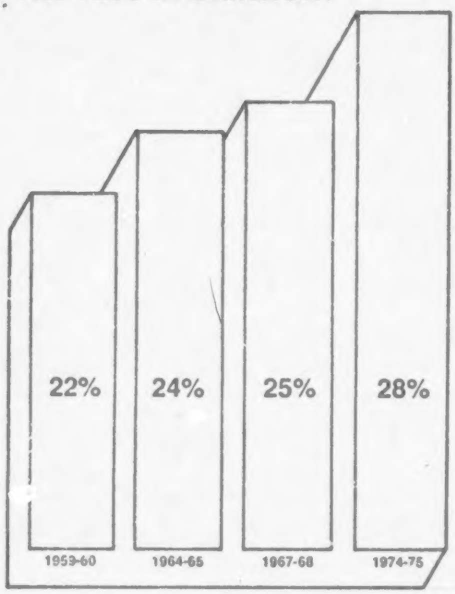
In Europe, this attention to shift work has deep roots: workers in the European guilds protested night work as early as the 13th Century. Negative reactions to shift work in the early 1800s resulted in an English law limiting the hours of work for apprentices in 1802.

England, Germany, France and Switzerland created government agencies to control the working conditions of shift workers around the turn of the century. Complaints about night work and regulations controlling it probably go back to the time when the first community of men found it necessary to post guards around the clock.

**In the United States,** no laws deal specifically with shift work. However, some laws affect shift work scheduling, such as the Fair Labor Standards Act (FLSA), Walsh-Healey Act, and the Work-Hours Contract Act. Generally, U.S. workers deal with the subject through collective bargaining, with 80 percent of the major collective bargaining agreements in 1975 including some reference to shift work.

But while there are no specific laws, related federal statutes are among the factors that must be weighted in consideration of shift work, along with the rate of pay or shift differentials, sequence of shift rotation, frequency of shift changes, the number of crews to be used, hours of rest, and the human

## The Rise in Shiftwork



physiological, psychological and social factors. Many of these factors are interrelated.

The design of shift work inevitably touches on federal and state laws dealing with the number of hours permitted per day or per week without an overtime penalty. The basic law, the FLSA, requires time and one-half premium for hours worked in excess of 40 hours per week. Other details affect shift work. FLSA regulations detail what is meant by hours of work; for example, a lunch period of 20 minutes or less is considered work time and not time off the job. This can be used as a form of shift bonus; for example, the day shift may work from 8 a.m. to 4:30 p.m. with a staggered, one-half hour, unpaid lunch period, providing continuous coverage for 8½ hours. The second shift, or evening shift, then works from 4:30 p.m. to 12:30 a.m. with staggered 20-minute, paid lunch breaks, giving 8 hours of continuous coverage. On the second shift, the worker really works seven hours and 40 minutes for eight hours of pay, but continuous coverage is provided for the plant. These shortened work periods on the second shift are then described as a shift bonus of 20 minutes. Twenty minutes is not enough time for a decent lunch break and cannot be considered as time off the job under FLSA.

**The third shift,** or the night crew, must complete the 24-hour coverage from 12:30 a.m. to 8 a.m. They also receive another 20-minute staggered meal break —at this time of night it is hard to call it a lunch break. Nevertheless, the result is 7½ hours of coverage, generally at eight hours of pay for 7 hours, 10 minutes actual time on the job.

This method of integrating the FLSA regulations into shift work schedules and treating the 7½ hours of coverage for the third shift as a bonus works out to less than 7 percent.

There are other statutes such as the Walsh-Healey Public Contracts Act and the Work-Hours Contract Act that also bear on shift work scheduling. This law applies to workers providing goods to the federal government through contracts and requires an overtime premium for all hours in excess of eight per day, or 40 per week. Thus, if the employer has a government contract, the spacing of work schedules during shift changes can become critical.

**Studies of shift work** show union representation particularly effective in winning shift work differentials. For instance, in the predominantly unionized basic steel industry, 48 percent of the workforce works on late shifts and all 48 percent receive premium pay for the odd hours. In the textile industry, not so highly organized, a similar percentage, 47.2, works the late shift, but with only 18.7 percent receiving shift differentials.

Shift work premiums in major union contracts are paid in three basic ways:

—an extra percent of the basic hourly rate;

—a fixed rate of additional cents per hour for the shift work; and

—the same basic daily pay, but with fewer hours to earn it.

A 1975 survey of 1,514 major private sector labor agreements showed 80 percent (a total of 1,214) had shift premiums of some type. A money differential was paid in 78 percent of these, 12 percent use the shorter hours for the same money as a premium, 6 percent combined shorter hours with a premium rate and 4 percent were in a miscellaneous category.

A similar BLS survey of public sector workers showed that 41 percent of the union contracts provide for money shift work premiums, but none of the state and county agreements surveyed contained one of the other forms of shift work differentials.

In both the public sector and private sector agreements, the cents per hour premium is the most common. In that 1975 study of major private sector agreements, the second shift average was 16 cents per hour and 21 cents per hour for the third shift. When the percentage form of shift premium is used, as it was in 20 percent of these agreements, the average second shift premium was 8 percent while the average third shift premium was 10 percent.

The percentage approach, of course, tends to maintain wage differentials, keeps pace with negotiated wage increases and doesn't need the frequent review required in the cents-per-hour method.

The Steelworkers' major steel agreements provide

20 cents per hour premium for the afternoon shift and 30 cents per hour for the night shift. Steelworkers at Textron Inc. in Connecticut receive a 17 percent premium for all work on either the second or third shift.

**A Machinists' analysis** of the shift work provisions in their agreements noted a difference in the direction or sequence of shift rotation. The most common is the chronological rotation of shifts from day, evening to night as opposed to the opposite direction of day, night to evening rotation. Interestingly enough, some physiological studies of the impact of shift rotation on workers tend to show a lesser impact if the cycle rotation is counter to the chronological order rather than chronological. Air travelers and crews also comment on the difference in their ability to adjust depending on whether the trip was east to west or west to east.

The Machinists note that in some shift schedules the number of hours at rest during the cycle rotation are affected. Time off between shifts varies widely. Some old schedules required a crew to work a 16-hour turn during rotation. Many of the more modern schedules provide 25 hours to as much as 72 hours off. Thus, the placement and number of hours off for rest on a shift schedule should be considered in terms of the optimum benefit to the worker.

The weekly rest period making free Sundays available to the worker are also important. The seventh day falling in mid week doesn't help family and social life much even though it may be a better day of rest. This, of course, varies with the design of the system adopted and the length of the cycle. In some cases, the Sunday may go in conjunction with a free Saturday, giving a free weekend to the worker. However, in most shift schedule designs, this cannot happen more than once during a given cycle of rotation.

The length of cycle rotation is the amount of time it takes for the worker to complete one full sequence of the schedule. Short or rapid rotation cycles appear to appeal to some as equitable. But, when viewed in terms of the ability of the body to adjust to the changes, it can become abusive. However, if the period on nights is short enough, the body systems may not change and the harm may be minimized.

**Man is a diurnal creature** as opposed to the nocturnal cat, bat and owl. Man normally awakens with dawn, presumably because of built-in physiological rhythms. The cycle of sleeping-waking revolves around a 24-hour period and is quite stable.

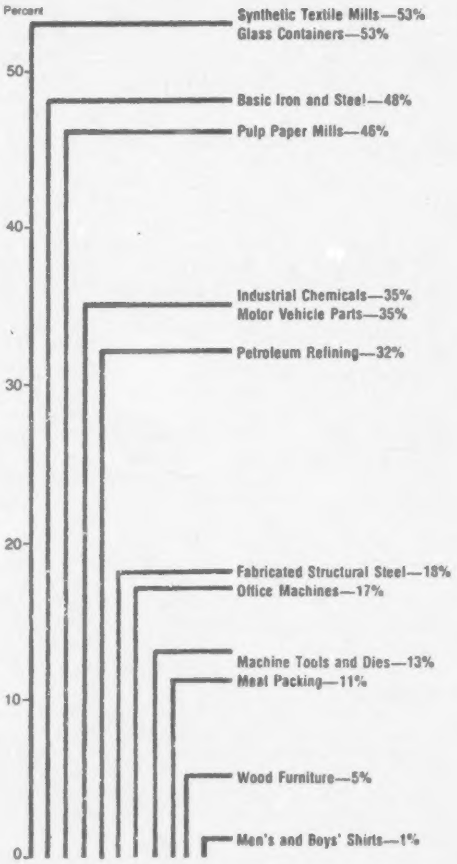
What happens when a worker does shift work? Do these cycles change to accommodate the shift pattern? How long does it take a worker to adjust to a new shift cycle of eating, sleeping and working?

Research on body function cycles is not sufficiently complete to indicate a best period of rotation. Clearly some workers adjust more quickly than others, and older workers have more trouble with rotation than younger workers; that is about all that is known now.

Some years ago, a professor and a student spent over a month in a cave. They tried to live first a 21-hour day and then a 28-hour day. The younger student's body was able to adapt but the 40-year old's body wanted sleep when the schedule said he should be awake. Later, similar studies indicated that some of the younger man's functions continued on the 24-hour cycle, though others adapted. How long the body can remain healthful with some body functions on a different time schedule than the others is a matter of conjecture.

Evidence of the physiological effects of shift work on worker's health is confusing and contradictory, with no definition of what is meant by "adverse

## Shiftwork in Different Industries



effects." Some researchers conclude no adverse effect as long as the worker doesn't get sick. Others found the workers healthy but with changes in some body systems. Still other researchers found problems with the way the previous studies were designed. Most of these researchers would like to continue to study the problem by following the work and health history of workers—a "longitudinal study" of up to 40 years, which is not much help for today's workforce.

No researcher has found that shift work is good for the worker, although some individual workers obviously thrive on it—or at least think they do—for the short term. Based on the evidence now available, it is obvious that the number of European countries passing laws is motivated by concern with the health of shift workers.

In June 1975 a National Institute for Occupational Safety and Health (NIOSH) symposium on shift work and health was the first in-depth gathering of information on the U.S. experience, although Europeans have done it since the 1950s. The NIOSH symposium resulted in no different conclusions except the need for more research, but material presented is instructive when combined with the earlier studies.

**The human body** has many functions that follow a rhythm—eating and sleeping are the most common. But there are many daily body rhythms that the average person is not aware of. There is a regular daily ebb and flow of the worker's body temperature, blood pressure, pulse, respiration, blood sugar, hemoglobin level and amino acid level. Other body rhythms have longer cycles, such as the female's monthly cycle.

In the early 1950s, the Strategic Air Command, in its concern over the effects of global flights on the flight crews, learned that crossing time zones resulted in an incomplete adjustment of the sleep-wakefulness cycle.

Similarly, the Federal Aviation Agency study found in the mid-1960s that disruptions of the work, sleep, eating cycle resulted in impairment of the crew's ability to concentrate, that their reaction time increased, and that general mental alertness decreased. This study found that it took four to five days for the average person to adjust to a five-hour change in schedule.

The effects of shift work on a worker's physical condition and psychological well-being has an effect on the worker's family and social life. A parent who arrives home at 1 a.m. will not feel much like going camping with the scouts at 7 a.m. Saturday. Thus, physiological fatigue will affect the parent's role and in turn, worker's psychological images of themselves as parents.

The average worker gets 7½ hours of sleep per night, while shift workers as a group average 6½ hours, and those on the night shift only 5½ hours per night. This difference in sleep and relationship to the community's social patterns has overlapping effects, but most research deals with the effects of changing body cycles and their effect on human health.

In another series of studies involving mice, changing the wake-sleep patterns 180 degrees decreased the life span by 6 percent. The same research found no adverse effect if the sleep-wake patterns were changed prior to birth, but this latter finding is of rather limited usefulness. In terms of practical application, this constitutes probable evidence of long-term low-level adverse effects.

**A Swedish experiment** concluded that approximately 28 percent of the workforce is unable to adapt to shift work. This is because the biological clocks that control the various systems within the body are more adaptable for some individuals than others. This is one reason the French now require physicals of workers assigned to shift work. Other research indicates that as workers grow older, the time for the biological clocks to adjust to changes increases. That is, younger workers appear more able to adapt to changes in the sleep-wake patterns of shift work than older workers.

Recently, it has been found that the effects of drugs given at different times in relation to the body's biological clock cycles show that with careful timing toxic side effects can be reduced and beneficial aspects of drugs enhanced. It follows that toxic chemicals introduced into the body could affect the worker differently depending on the time of exposure. This fact has not been taken into consideration when developing our occupational safety and health standards but it is used when treating diseases.

Thus, it seems as though the shift worker may lose on both accounts: (1) exposure to toxic substances may affect them more severely and (2) when they go to the hospital for treatment it may be less effective. Shift work may have caused the biological body cycle to behave in a less predictable fashion or at least in a fashion unlike that of the normal day worker on which treatment normally is based. Thus, the proper timing to administer a particular treatment may not be as available to the shift worker.

Occupational health and safety standards are based on the assumption that workers work eight hours a day, 40 hours per week. BLS data clearly indicate that over the years the average work week is about 40 hours, but in many situations the work week is made up of 10-hour days when overtime is involved. Some shift work schedules, at the time of rotation, involve a 16-hour exposure, or the time away from the exposure is much less than 16 hours normally enjoyed by non-shift workers. Prolonged exposure to toxic substances at levels based on an eight-hour day standard can result in increased total dose to the body. These prolonged doses burden the body's defense mechanisms and increase the possibility of disease.

**Historical concern** and the rationale for shift premiums have focused on the adverse social effects of night work. These concern social deprivation, but little was known about the consequences of this social isolation until recently.

A 1953 British study by Wyatt and Marroitt indicates a higher divorce rate among shift workers. A later study by Banks in 1956 looked at some of the domestic problems. Interviews with wives showed they were upset about leisure time falling in mid-week and a lack of family activity on weekends stemming from rotating shifts. A 1965 American study was based on interviews of shift workers indicated difficulties in performing the usual domestic roles and the irregular hours interfered with the usual home life. Additionally, these problems tended to be cumulative, resulting in general reduction in marital happiness. Although more research is needed, there can be little doubt that shift work and particularly rotating shifts place stress on domestic relations that would not otherwise exist.

Studies on the parent-child relationship have dealt only with the parent's views. If shift work disrupts the normal family roles as indicated above, then it would be worthwhile looking to the relationship between shift work and delinquency rates, truancy problems, school performance and other factors relating to the effects on children. Even without hard evidence, workers on shift work report that they feel that their relationship with the children suffers, particularly with the rotating shifts.

The general level of social activity for shift workers has also been found to suffer; their friends are fewer and mostly tied to work; they belong to fewer organizations and are less likely to hold office in them. But these organized social activities aren't as important to workers, the interviews show, as are domestic dysfunction and damage to informal social activities.

**A number of studies** have related shift work to accidents. One of the better ones is based on 11,000 accidents. This study indicates differences in accident rates between shifts were rather small; that is, the number of accidents relative to the number of workers was about the same. However, the seriousness of the accidents occurring on the night shifts are significantly higher than on the day or afternoon shift.

The fact that the studies are conflicting is illustrated by a 1960 German study by G. H. Bast concluding that dissatisfied shift workers are neurotic, while a 1965 study by the Institute for Social Research of the University of Michigan found no such relationship.

However, an interesting finding of the Michigan study is that the on the job psychological health of the shift worker may be better than that of the day worker. One reason suggested is that the pressures are greater on the day shift, with more supervisors present than on night shifts.

Other research indicates that adverse psychological effects are less severe or non-existent if shift work is a part of the historical pattern of the community. That is, workers in a new plant in a community which has not had shift work will feel the effects more severely than if the same plant were located in a community where shift work was common.

In short, shift work does seem to adversely affect the psychological health of the worker, but this effect stems from workers' perceptions of themselves off the job rather than from functions on the job. This is one area of worker satisfaction-dissatisfaction that needs a great deal more research.

Worker attitudes toward various types of shift work differ greatly. The fixed night shift tends to be the most physically disruptive shift assignment. Physiologically, large numbers of workers cannot adjust. No sooner do their bodies begin adapting to nights then the weekend comes and the workers go to the day schedule to meet social and domestic demands. They really cannot meet most of their parental roles and this presents additional problems. Productivity of long-term night assignments appears to be lower than the other options. Yet with seniority, workers have the opportunity to leave the shift in time.

The fixed afternoon shift also has some problems but not as severe as the night shift. The afternoon shift's major problems tend to be in the domestic area. Most other problems tend to be rather minor or ones that workers are able to adjust to.

**The rotating shift** is the most difficult to deal with. The physical effects are severe, social and domestic problems difficult to cope with, and the effect on the body's various time cycles is a matter of concern. In 1978 a Stanford Research Institute study found that rotating shift workers reported significantly more stomach and digestive problems, leg and foot cramps, colds, chest pains, fatigue, menstrual problems, nervousness and shakiness, alcohol consumption, wheezing and use of sleeping stimulus. Institutionally, workers do not like rotating shifts; and if the issue is voted on, they will normally vote for fixed shifts with shift rights based on seniority. However, if shift work is a must, they prefer a rapidly rotating shift.

Realistically, this makes sense. Long rotation cycles do not help the worker on the night shift, due to weekends, and there are more and more three-day weekends, the body systems never do adjust on long shift rotations. The best approaches may be four, or even five, crew shift schedules that allow the three full days off following the night turn with as few days on nights as possible. Three or four days on nights and rotating off as quickly as possible with a long rest period after the night turn seems the best solution.

Shift assignments based on seniority relieves older workers from the physical burden of trying to cope with rotating shifts. Some younger workers also have real physiological problems with rotating shifts, which should be determined at the time of hiring.

**As long as attention** is paid to a company's cost-benefit ratio rather than the whole social, economic and physiological cost, analyses of shift work will be directed at only making the best of a poor situation. There is a great deal of evidence that shift work is not socially or, in the long term, economically desirable.

For some jobs like police and public utilities, shift work is essential, but there are others where it is required for the limited economic advantages of the employer. In these cases the cost to the worker, the family, and community should receive greater consideration.

APPENDIX II

IAM RESEARCH REPORT

INTERNATIONAL ASSOCIATION OF MACHINISTS AND AEROSPACE WORKERS
MACHINISTS BUILDING, WASHINGTON, D.C. 20036

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# Continuous Operations—A New Challenge

In this age of highly sophisticated plant and equipment the high cost in terms of both initial investment and operation has caused American industry to seek new ways of maximizing the utilization of its machinery. One way which is becoming increasingly common is to initiate continuous operations, *i.e.* twenty-four hours per day, seven days per week.

While long a practice in certain basic industries, continuous operations are now being instituted in industries where IAM representation is substantial. This has led to problems for IAM negotiators. Conditioned by both past bargaining experience and personal trade union philosophy, IAM representatives are committed to the traditional concept of a work week, *i.e.* Monday through Friday with overtime payments for work on Saturday and/or Sunday.

The purpose of this article is to review the basic concept of continuous operations and, then, examine some of the systems by which continuous operations are being implemented. In this way, the IAM Field Staff will be better prepared to tackle this issue at the bargaining table.

The traditional means of scheduling continuous operations is with a three-shift system. It would be impossible to describe all of the existing and/or possible three-shift systems. Instead, there will be a general discussion of the principles involved in three-shift operations and then a description of the most commonly used system (including some innovative alternatives to the three-shift system for continuous operations).

The basic elements in any three-shift system include the number of crews used, the frequency of change of shift, the direction of rotation, the length of the cycle of rotation, the number of consecutive hours of rest and the way in which those hours are distributed over the cycle, and the number of free Sundays in the cycle.

### Frequency of Change of Shift

The frequency of change of crews among the various shifts can vary from two days to every two-weeks or more. Weekly changeovers are the commonest, and as will be seen below this may in fact correspond simply to a period of working five or six days of work performed between two rest periods. Weekly changeovers of shift would seem to be a compromise between a short cycle of rotation (two or three days) and a long cycle (two weeks or monthly).

### Direction or Sequence of Rotation

Shifts may rotate in chronological order (morning, afternoon, night) or in the opposite direction (night, afternoon, morning). This affects the distribution of the hours of rest during the cycle of rotation: thus in a three-week cycle including 120 hours off at times when shifts change over, the normal direction of rotation (morning, afternoon, night) gives successively two weekly rest periods of 48 hours and one of 24, while the opposite direction (night, afternoon, morning) gives, in succession, two weekly rest periods of 32 hours and one of 56. In certain cases this may have the effect of making the weekly rest period coincide with the weekend.

### Length of Cycle of Rotation

This is the period necessary for an individual worker to come back to the same sequence of days of work and rest over a number of weeks. This length may vary from three to twenty weeks, at least in the systems most commonly used. It is determined, in part, by the number of crews required under the system adopted.

### Hours of Weekly Rest and Their Distribution

As already pointed out, the frequency and direction of rotation determine the length of the weekly rest periods and their distribution over the days of the week. Thus, these factors in combination can lead to a variation in the length of the weekly rest period from 24 to 72 consecutive hours in the same cycle.

### Number of Free Sundays

Depending on the system adopted and the length of the cycle, the number of free Sundays will vary, so that there will be either one free Sunday every four weeks or three free Sundays every nine weeks. In certain cases a Sunday may go with a Saturday, giving a free weekend, but this cannot happen more than once at most during any given cycle of rotation.

### Number of Crews, and Related Variations

Since we are dealing with a three-shift system, it may appear at first sight, that all that is necessary for the operation of such a system is to divide the workers up into three crews. This was, in fact, the arrangement most commonly used when the system was first adopted. It had the serious disadvantage, however, of requiring one of the crews to work a double shift at the end of the week so as to facilitate the rotation of the crews on each particular shift (morning, afternoon and night) and to enable the other two crews to have a continuous rest period of 24 hours. Other systems have gradually been developed to overcome this difficulty, as well as to reduce the average number of hours worked per week and to increase the number of rest days in the week. The use of a fourth crew is now widespread and provides the basis for what has sometimes been called the "rotating week".

This system enables one crew to rest while the other three are working; as a result, if account is taken of the rotation of the crews among the three shifts (morning, afternoon and night), rest days are spaced out over the week. Thus, for a four-week cycle, one crew will be able to rest on Monday and Tuesday in the first week, on Wednesday and Thursday in the second, on Friday and Saturday in the third and on Sunday and Monday in the fourth. Each crew is thus certain to have one Sunday free during the cycle of rotation.

It is due to the variation in the above factors that make it possible to arrange numerous systems of rotation such that continuous operation is possible throughout the 168 hours of the week. The possibility of changing from one system to another will depend, however, on the average daily number of hours of work that each shift performs or is desired to perform.

### Current Practice

The steel, glass, petroleum, chemical and paper industries have traditionally operated on a continuous basis, hence the term "shift work." The scheduling is handled in either of two ways. The first, with three crews on a fixed shift with a "swing" crew rotating to fill up the work-day "gaps", or all four crews rotating on a weekly basis (the least desirable from a worker standpoint). An example of the "swing crew" schedule is as follows:

**FIRST WEEK**

| | Sat. | Sun. | Mo. | Tu. | We. | Thu. | Fri. | |
|---|---|---|---|---|---|---|---|---|
| 7:00 a.m.- 3:00 p.m. | A | A | A | A | A | D | D | 1 Shift |
| 3:00 p.m.-11:00 p.m. | D | D | B | B | B | B | B | 2 Shift |
| 11:00 p.m.- 7:00 a.m. | C | C | D | C | C | C | C | 3 Shift |

**SECOND WEEK**

| | Sat. | Sun. | Mo. | Tu. | We. | Thu. | Fri. | |
|---|---|---|---|---|---|---|---|---|
| 7:00 a.m.- 3:00 p.m. | D | D | A | A | A | A | A | 1 Shift |
| 3:00 p.m.-11:00 p.m. | B | B | D | B | B | B | B | 2 Shift |
| 11:00 p.m.- 7:00 a.m. | C | C | C | D | D | C | C | 3 Shift |

**THIRD WEEK**

| | Sat. | Sun. | Mo. | Tu. | We. | Thu. | Fri. | |
|---|---|---|---|---|---|---|---|---|
| 7:00 a.m.- 3:00 p.m. | A | A | D | A | A | A | A | 1 Shift |
| 3:00 p.m.-11:00 p.m. | B | B | B | D | D | B | B | 2 Shift |
| 11:00 p.m.- 7:00 a.m. | C | C | C | C | C | D | D | 3 Shift |

**FOURTH WEEK**

| | Sat. | Sun. | Mo. | Tu. | We. | Thu. | Fri. | |
|---|---|---|---|---|---|---|---|---|
| 7:00 a.m.- 3:00 p.m. | A | A | A | D | D | A | A | 1 Shift |
| 3:00 p.m.-11:00 p.m. | B | B | B | B | B | D | D | 2 Shift |
| 11:00 p.m.- 7:00 a.m. | D | D | C | C | C | C | C | 3 Shift |

**(Letter designations indicate different employees, or groups of employees.)**

In industries where these schedules are prevalent, there are no premium payments for Saturday and Sunday work as such, however, time and one-half is generally paid for the sixth consecutive day worked and double time for the seventh. Lunch periods of 20 minutes to ½ hour are paid for and rest periods, if any, are limited to 10 minutes each half shift.

Innovations recently adopted by other industries such as aluminum and metal container have attempted to overcome some of the disadvantages and onerous work arrangements of the traditional schedules. *Schedule I* is the type adopted by Reynolds Aluminum utilizing four rotating shifts. However, because they do not pay premium pay for Saturday and Sunday as such, but rather for the sixth and seventh day worked, their average weekly hours paid over a 28 day cycle is 46 for 42 hours work, whereas Continental Can Company under the same type schedule would pay for 51 hours for 42 hours worked. Although Reynolds seems to have an advantage in not paying Saturday and Sunday premium, they do pay another type of continuous operations penalty outlined in G of *Schedule I*.

*Schedule II* is the same type as Reynolds but with four crews, three on fixed shifts and one "swing" crew. The same advantages would prevail in this schedule with overtime payments for the sixth and seventh day rather than Saturday and Sunday as such. This arrangement has generally been adopted by National Can (with Saturday and Sunday premium, however).

*Schedule III* outlines the shift arrangements used thus far by Continental and American. This schedule provides for three crews on the three fixed shifts with each crew overmanned to provide rotating days off within the crew. Although the exhibit indicates an eight-hour shift with paid lunch period. Continental has established initial schedules of two 8½ hour shift and a short third shift. Again, the cost factor is the premium pay for Saturday and Sunday as such. This schedule has been most acceptable to employees who have traditionally worked on a "regular" shift without the disadvantage of a rotating or "swing shift" arrangement.

*Schedule IV* is the latest innovation in seven day scheduling adopted first by Schlitz and later utilized by Jeffco. This method utilizes four crews working fixed 12-hour shifts, two crews on—two crews off. Schlitz pays time and one-half for all hours worked over eight in a day or for work performed on scheduled days off—no premium for Saturdays and Sundays. Jeffco modified overtime payments to provide for time and one-half for hours worked over 34½ hours in the three-day week schedule and for hours worked over 40 in the four-day week schedule—again, no Saturday and Sunday premium. They do, however, pay a 25¢/hour premium to all employees on continuous operations which probably more than offsets the slight overtime payment advantage over Schlitz.

### Other Factors

It should be kept in mind that continuous operations are costly from managements point of view; mainly because of the need to promote, train and pay (both wages and fringes) 25 percent more maintenance and operating personnel. Once inaugurated, continuous operations must be assured for a long term because any economic advantage can be lost or diminished if production schedules vary so that the "over-manned" operation cannot be sustained over a long period.

Further, there is a considerable difference of opinion as to whether it is better to give each man an equal opportunity on each of the shifts or fit the man by choice, if possible, into fixed hours. This latter system is represented by non-rotating shifts. When such schedules are in practice, employees can have standard eating and sleeping hours. As against this, however, is the practical impossibility of giving each man his choice of shift. The 12:00 midnight to 8:00 AM or in some cases, the 11:00 PM to 7:00 AM shift, usually referred to as the "graveyard" shift, is generally considered the undesirable one. Some companies have found it difficult to man this shift, reporting that if seniority were made the basis for the shift assignments, then this "graveyard" shift would be made up for the most part of relatively green men. Companies in deciding this problem have had to consider the employee's attitude, which with regard to this question is quite varied. The controlling factor for the employee, however, seems to be dependent upon local community practices.

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Finally, it should be kept in mind that the introduction of continuous operations involves important problems of adjustment for the worker, the community, and management. Night shifts and Saturday and Sunday work mean significant changes in the living arrangements of employees in families and communities on a daytime, 5-day week schedule. Night workers need the use of eating, recreation and transportation facilities, normally operated primarily for day workers. Establishing and maintaining multiple shift and weekend operations create important problems regarding the scheduling of hours of work, the recruitment, assignment and rotation of workers on extra shifts, and the training of skilled and supervisory workers.

### Conclusion

The decision as to whether or not a particular company will spend the capital investment necessary to require continuous operations is made by its management. The economics of the market place determine that decision. What has not been decided is whether these new operations and/or plants will be organized or not and, if so, by whom?

A key element in answering these questions may well be how flexible IAM negotiators are in viewing the work week. Certainly there are those who will argue that to consider giving up Saturday and Sunday overtime, as such, the IAM would be both betraying trade union principles and reducing the earnings of some of our present members. In considering this, it should be remembered that the purpose of overtime has been and still is to place a *penalty* on management sufficient to discourage overtime and encourage the hiring of additional workers. Overtime was not designed as a means of increasing a workers' earnings. Continuous operations meet both objectives: overtime is reduced and there is a potential employment increase of 25 percent.

The above is not meant to suggest that we automatically give up our traditional principles without long and careful consideration of all implications. Rather, this report is designed to provide the necessary background data with which our Field Staff can, if necessary, adopt a position flexible enough to meet the changing technological requirements of American industry. Copies of actual work schedules for continuous operations at IAM plants are available from the Research Department upon request.

## SCHEDULE I

A. Three shifts per day.
B. Four Crews
C. Individual stays with crew which rotates each week to new shift.
D. Although the four crews start on different days, the net effect of the schedule is work seven days—off four, work seven—off two, work seven—off one. This completes a 28 day cycle where each employee has worked 7 days on each shift for a total of 21 days worked and has been off 7 days (including one 4-day weekend).
E. Overtime is paid at time-and-one-half for hours worked on the 6th consecutive day worked in the work week or for time worked on Sunday, and double time is paid for work performed on the 7th consecutive day in the work week.
F. Economics:
Figures apply to individual employee and represent average per week over the 28 day cycle:

| | All Shifts |
|---|---|
| Hours worked | 42 |
| Hours paid | 46 |

G. Reynolds shifts are eight hours duration including a 20 minute paid lunch period. Above economics do not tell entire story as Reynolds pays a 30¢ per hour premium for continuous operations plus a bonus of three job classes which at the present time amounts to 27.9¢ per hour worked. (Total premium and bonus equals 57.9¢ per hour).
H. 7 days on, 4 days off 1 four-day weekend off/4 weeks
7 days on, 2 days off 7 total days off/4 weeks
7 days on, 1 day off

1st week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| A | A | A | A | B | B | B |
| C | D | D | D | D | D | D |
| B | B | B | C | C | C | C |

2nd week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| B | B | B | B | C | C | C |
| D | A | A | A | A | A | A |
| C | C | C | D | D | D | D |

3rd week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| C | C | C | C | D | D | D |
| A | B | B | B | B | B | B |
| D | D | D | A | A | A | A |

4th week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| D | D | D | D | A | A | A |
| B | C | C | C | C | C | C |
| A | A | A | B | B | B | B |

## SCHEDULE II

A. Three shifts per day.
B. Four crews.
C. Individuals on three of the crews stay on the same shift. Individuals on the 4th crew rotate through all three shifts each week. Although the four crews start on different days, the net effect of the schedule is work seven days—off four, work seven—off one, work seven—off two. This completes a 28 day cycle where each employee has worked 21 days and has been off 7 days (including one four-day weekend).
D. Overtime is paid at time-and-one-half on Saturday and double time on Sunday.
E. Economics:
Figures apply to individual employee and represent average per week over the 28 day cycle:

| | 1st & 2nd Shift | 3rd Shift* | 4th Crew** |
|---|---|---|---|
| Hours worked | 42 | 34.125 | 39.375 |
| Hours paid | 51 | 51 | 51 |

*3rd shift is 6½ hours, paid for 8.
**Rotating crew.

F. 4 crews: 3 fixed shifts
1 rotating—crew D

7 days on, 4 days off 1 full four-day weekend off/4 weeks
7 days on, 1 day off 7 total days off/4 weeks
7 days on, 2 days off

1st week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| A | A | A | A | D | D | D |
| B | B | D | D | B | B | B |
| C | D | C | C | C | C | C |

2nd week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| D | A | A | A | A | A | A |
| B | B | B | B | D | D | D |
| C | C | D | D | C | C | C |

3rd week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| A | D | A | A | A | A | A |
| D | B | B | B | B | B | B |
| C | C | C | C | D | D | D |

4th week

| M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|
| A | A | D | D | A | A | A |
| B | D | B | B | B | B | B |
| D | C | C | C | C | C | C |

## SCHEDULE III

### AMERICAN CAN

A. Three shifts per day.
B. Three overmanned crews (25% overmanned).
C. Individual stays on same shift.
D. Individual employees within a shift are scheduled to work (using up the overmanning) six days—off two, work six—off two, etc. until an eight week cycle is completed. Each employee will therefore have worked 42 days and been off 14 each cycle (including 2 two-day weekends).
E. Overtime is paid at time-and-one-half on the sixth day.
F. Economics:
Figures apply to individual employee and represent average per week over the 56 day cycle:

| | |
|---|---|
| Hours worked | 42* |
| Hours paid | 45.50 |

*each 8 hour day includes a 20 minute paid lunch.

### CONTINENTAL CAN

A. Three shifts per day.
B. Three overmanned crews (25% overmanned).
C. Individual stays on same shift.
D. Individual employees within a shift are scheduled to work (using up the overmanning) seven days—off two, work seven—off two, work seven—off three. This completes a 28 day cycle where each employee has worked 21 days and has been off 7 days (including one three-day weekend).
E. Overtime is paid at time-and-one-half on Saturday and double time on Sunday.
F. Economics:
Figures apply to individual employee and represent average per week over the 28 day cycle:

| | 1st & 2nd Shift | 3rd Shift* |
|---|---|---|
| Hours worked | 42 | 34.125 |
| Hours paid | 51 | 51 |

*3rd shift is 6-½ hours—paid for 8.

3 crews—3 fixed shifts each crew overmanned—providing for coverage within each crew for days off.
3—8 hour shifts/day
paid lunch
4 week cycle

7 days on, 3 days off
7 days on, 2 days off
7 days on, 2 days off

| | |
|---|---|
| Avg. Hrs. worked/week: | 42 |
| Avg. Hrs. paid/week: | 51 |

1 full 3-day week end off/4 weeks
7 total days off/4 weeks

The following represents one shift—each shift will be exactly the same and each shift has the following segmented crew:

| Segment Symbol | Men | Explanation |
|---|---|---|
| W | 6 | Three segments totaling |
| X | 6 | 18 men on each day |
| Y | 6 | 1 segment equaling 6 men |
| Z | 6 | Off each day |
| | 24 | |

| Segment | M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|---|
| | | | 1st week | | | | |
| W | Off | Off | On | On | On | On | On |
| X | On | On | Off | Off | On | On | On |
| Y | On | On | On | On | Off | Off | Off |
| Z | On | On | On | On | On | On | On |
| | | | 2nd week | | | | |
| W | On | On | Off | Off | On | On | On |
| X | On | On | On | On | Off | Off | Off |
| Y | On | On | On | On | On | On | On |
| Z | Off | Off | On | On | On | On | On |
| | | | 3rd week | | | | |
| W | On | On | On | On | Off | Off | Off |
| X | On | On | On | On | On | On | On |
| Y | Off | Off | On | On | On | On | On |
| Z | On | On | Off | Off | On | On | On |
| | | | 4th week | | | | |
| W | On | On | On | On | On | On | On |
| X | Off | Off | On | On | On | On | On |
| Y | On | On | Off | Off | On | On | On |
| Z | On | On | On | On | Off | Off | Off |

Note: Cycle repeats every 4 weeks.

## SCHEDULE IV
### SCHLITZ/MILLER

A. Two shifts per day (11-½ hours).
B. Four crews.
C. Individual stays on same shift.
D. There are two crews for each shift. One of the two crews works four days then off three, while the other is off four days then works three. The following week they reverse and the first crew works three days—off four, while the second crew works four days—off three. Wednesday of each week is the alternating day (crew that works first Wednesday is off the next Wednesday). The second shift works the same way. This completes a two week cycle where each employee has worked seven days and has been off seven days (each crew gets two Saturdays or two Sundays off per cycle, but not both). Crews reverse each six months so that those with Sunday off for the past six months get Saturday off for the next six months.
E. Overtime is paid at time-and-one-half for hours worked in excess of eight per day, or for days worked on scheduled days off. Double time is paid for work performed on the seventh day (or last scheduled day off) of the work week.
F. Economics:

Figures apply to individual employee and represent average per week over the two week (14 day) cycle:

| | 1st or 2nd Shift |
|---|---|
| Hours worked | 40.25 |
| Hours paid | 46.375 |

There is no 3rd shift.

### BALL CORP. (WILLIAMSBURG) JEFFCO

A. Continuous operations are handled identically to Schlitz except for calculation of overtime.
B. Overtime is paid at time-and-one-half for hours worked over 34-½ hours in the week where employee is scheduled for three days, and for hours worked over 40 in the week where employee is scheduled for four days. There is no 6th or 7th day, or Saturday and Sunday overtime as such, nor is there overtime pay for over eight hours in one day.
C. Economics:

Figures apply to individual employee and represent average per week over the two week (14 day) cycle:

| | 1st or 2nd Shift |
|---|---|
| Hours worked | 40.25 |
| Hours paid | 41.75 |

There is no 3rd shift.

D. A premium of 25¢ per hour is paid all employees on continuous operations.

| Shift | 1st week M | T | W | T | F | S | S | 2nd week M | T | W | T | F | S | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | A | A | B | B | B | A | A | A | B | B | B | B | A |
| 2 | C | C | C | D | D | D | C | C | C | D | D | D | D | C |

Mr. **Zalusky**. The process of collective bargaining is facilitated by practical information that integrates the scientific knowledge available in a fashion that is suitable for practical application.

Unions have for some time been dealing with various approaches to this. One of the experiments that has been going on now is in the aluminum industry, where they have been working 12-hour shifts, 36 hours a week. I tend to get the feeling it is more based on cost effectiveness than the physiological problems or social consequences of it. What we do need is more information that goes directly to addressing these problems and how to approach them.

A major step was made by the National Institute for Occupational Safety and Health when they began investigating shift work in the early seventies and putting together research on sleep patterns and physiological rhythms in human performance studies.

A NIOSH-sponsored symposium was held in 1975. There was another conference held in 1979. The papers presented were a major step toward an integrated approach to the issue.

Although many scientists have been dealing with human problems associated with the effects of sleep patterns on biological performance, NIOSH's conference helped the scientific effort focus attention on the problems of shift work. The welding together of this information and knowledge of different disciplines in different countries has provided information on the problem of health consequences of shift work.

I want to call attention to the social problems as well. My interest in this comes from the fact that I was raised in a family that worked shift work and I myself worked shift work. As a young person, I remember growing up in a household with a shift worker. I felt the lack of a parent at Scout meetings, father-son school, and church affairs.

As a young working adult on shift work in a community where it was unusual, I noticed friendships slipping away as friends got tired of trying to determine what days and evenings I was available.

My personal relationships, except for family, slowly evolved to socializing with others on basically the same shift. In short, shift work dominated personal associations, leading to what sociologists call social isolation.

A great deal more research needs to be done with regard to the social consequences. The evidence to date seems to indicate that there is a relationship between shift work and domestic problems.

The effects of shift work on divorce rates, spouse abuse, drug use, and juvenile delinquency should be studied. There have been some European studies on this, but most of the American studies tend to deal with self-reporting: Did you have a problem with your wife? That type of thing.

There is some evidence that these problems are not as severe in communities where shift work is relatively common. However, a good deal more research needs to be done in this area.

Research must now be focused on practical strategies for dealing with the problems associated with shift work. Both labor and management would benefit from studies to effectively minimize the adverse effects of the forced fit of the worker's normal body cycles and social patterns into the shift work schedule. We urge that special funds be allocated to NIOSH to undertake such research.

I didn't put this in the prepared text, but the total cost of what NIOSH has done so far in the shift work studies is about $400,000 since the mid-seventies. The budget for all stress studies in fiscal year 1982 was $850,000. In fiscal year 1983 it has been cut to $300,000.

We estimate that to do the kind of studies that we think are necessary, for some practical strategies to deal with shift work, it would probably cost $1.5 million to $2 million in NIOSH funding spread over 3 to 4 years.

That concludes my remarks, Congressman.

I have a number of questions, but I am going to hold them until Dr. Ward has completed his testimony.

[The prepared statement of Mr. Zalusky follows:]

### PREPARED STATEMENT OF JOHN L. ZALUSKY, ECONOMIST, DEPARTMENT OF ECONOMIC RESEARCH, AMERICAN FEDERATION OF LABOR AND CONGRESS OF INDUSTRIAL ORGANIZATIONS

I appreciate the opportunity to present the views of the AFL-CIO on the problems associated with shift work.

Your interest in the problems of shift work demonstrates sensitivity to a problem that has long confronted the workers and a problem that has received too little attention. In recent years there has been a lot of discussion about alternative work schedules in the context of flexible work hours and other variations on the 8-hour day, 40-hour week, but shift work—the most common and oldest alternate work schedule—has hardly been addressed.

The scientific evidence available today clearly indicates that shift work causes stress and that it has a variety of physiological and sociological consequences. It also indicates that these effects increase with age. The problem is aggravated as the workforce is growing older and normal retirement under Social Security is being extended to age 67. With this in mind, it is time to begin looking to ways of coping with shift work as an economic, psychological and sociological problem that we believe is going to grow.

Shift work is used for a variety of reasons, but can be fit into four categories: (1) Work that requires round-the-clock coverage; for example: police, fire, hospital, and public utility services must be maintained on a continuous basis. (2) Continuous processes that cannot be shut down; for example: chemical plants and steel mills. (3) Work that is maintained for the convenience of the public, like all-night shopping and fast food service. (4) Work that is performed continuously to maximize capital recovery as quickly as possible. As technology advances, with rapid obsolence becoming a serious problem and the cost of capital relative to labor increasing, we believe there will be a continual increase in the demand on workers to work around the clock and through the weekends—24 hours, 7-day coverage.

About 16 percent of the workforce is on some form of shift work other than the usual day-work schedule according to data from the current Population Survey taken for the Bureau of Labor Statistics in September 1981. This proportion has remained quite stable since 1973 when BLS began asking these questions in their survey.

The movement to shift work in particular industries is demonstrated by an analysis of the Bureau of Labor Statistics' Industry Wage Surveys. In 1951, 32 percent of the productive non-supervisory workforce in petroleum refining were employed in rotating shifts. By 1965 the number had decreased slightly to 33 percent. But by 1981, 50 percent were on rotating shifts. The synthetic fiber industry had 42 percent of its workforce on rotating shifts in 1948, 45 percent in 1966, and 60 percent in 1981. Other industry studies show substantial use of shift work in gas and electric utility industry with 7 percent of its workforce on the second shift and 5 percent on the third. Shipbuilding has 25 percent on the second shift and 10 percent on the third.

The computer industry had 45 percent of its professional and technological staff on shift work in 1978. This varied significantly geographically from the northeast region, Nassau-Suffolk counties in New York to the Houston, Texas, area. Nassau-Suffolk had approximately 20 percent of its computer workforce on this second shift and 20 percent on the third, while the Houston area had 10 percent on the second shift and less than 10 percent on the third.

Unions have long been dealing with shift work. Today, most collective bargaining agreements have special provisions dealing with shift work. Generally, these contract provisions provide for worker shift selection based on length of service with the employer, premium pay for shift work and some provide for shorter hours on the second or third shift. The Machinists' Research Report gave its staff practical suggestions based on shift design past experiences.

The process of collective bargaining is facilitated by practical information that integrates the scientific knowledge available in a fashion that is suitable for practical application.

To provide direction based on growing information, there must be an integration of the scientific research associated with the physiological studies, sleep patterns and work performance.

The National Institute for Occupational Safety and Health (NIOSH) began investigating shift work in the early 70s by putting together research on sleep patterns and physiological rhythms in human performance studies. A NIOSH sponsored symposium was held in 1975 and again in 1979. The papers presented were a major step toward an integrated approach to the issue. Although many scientists had been dealing with human problems associated with effects of sleep patterns, on biological performance, NIOSH's conference helped this scientific effort focus attention on the problems of shift work. The welding together of this information and knowledge of different disciplines in different countries has provided information on the probable health consequences of shift work.

A great deal more research needs to be done with regard to the social consequences. The evidence to date seems to indicate that there is a relationship between shift work and domestic problems. The effects of shift work on divorce rates, spouse abuse, drug use and juvenile delinquency should be studied. There is some evidence that these problems are not as severe in communities where shift work is relatively common. However, a good deal more research needs to be done in this area.

Research must now be focused on practical strategies for dealing with the problems associated with shift work. Both labor and management would benefit from studies to effectively minimize the adverse effects of the forced fit of the worker's normal body cycles and social patterns into the shift work schedule. We urge that special funds be allocated to NIOSH to undertake such research.

Mr. GORE. Thank you very much.

Dr. Richard Ward, professor in the Department of Industrial Engineering at West Virginia University. Welcome. Please proceed.

[The biographical sketch of Dr. Ward follows:]

### RICHARD E. WARD, PH. D., P.E.

Dr. Ward is an Associate Professor of Industrial Engineering at West Virginia University, and a registered Professional Engineer in Pennsylvania and West Virginia. Dr. Ward teaches, conducts research, and practices in the general field of production management, and more specifically in the field of production and manpower scheduling. He has completed several contracts for the U.S. Department of Transportation dealing with transit operator and crew scheduling. He is a past National Director of the Transportation and Distribution Division of the Institute of Industrial Engineers, and is currently Vice President of the College Industry Council for Material Handling Education, which falls under the auspices of the Material Handling Institute. Dr. Ward also serves on the Academic Advisory Council for the Pittsburgh area chapter of the American Production and Inventory Control Society.

Dr. WARD. Thank you, and good morning.

I will take the liberty of summarizing my prepared remarks and try to touch on some of the most important points from my point of view.

I assumed you wanted my candid opinion in preparing testimony for this morning. However, I did do some research preliminary to doing that. It is perhaps significant to note my surprise at the discovery of so much literature actually devoted to the consequences of night and shift work. I think this omission on my part may underscore the significance of these hearings.

The facts related to who works night and shift work when expressed in percentages I found difficult to quantify, as I heard my colleague confirm some moments ago. Some of the figures that I have come up with indicate approximately 27 percent of the American work force involved in shift work with a growth in major metropolitan areas, somewhere in the neighborhood of 6 percent per decade. These figures, of course, are averages. In certain sectors of the economy you would find figures approaching 50 percent of the work force involved in shift work of some sort.

From a production planning point of view, decisions to move to second and third shift operations are governed principally by factors such as an increased demand for goods being produced, given existing plant capacities; the need to maximize the utilization of expensive or capital intensive production resources; and the characteristics of the production processes; as was mentioned earlier, such as chemical plants, petroleum plants, and the like.

From an academic point of view there has been nearly as much research published on the topic of production planning and methods for arriving at least cost plans as there has been published results of biological rhythms research.

The factors associated with these studies and the costs involved typically include things such as the cost of hiring, the cost of laying off, the cost of working overtime, subcontracting of the extra work, the banking of excess production from slack periods in order to cover subsequent peak periods, and the option of permitting back orders to accumulate during peak periods which can eventually be covered during subsequent slack periods.

I am not aware, however, of any published work which explicitly takes into account the health, safety, and social performance issues associated with shift work plans and options.

How industry implements worker shift assignments is yet another matter which varies considerably, depending on the industry. The most common scheme seems to be the fixed shift arrangement, where workers are assigned more or less permanently to one or more of the shifts. However, I did find it difficult to quantify exactly what "common" would mean and what percentage of the total work force is actually involved in fixed shift schemes.

Similarly, in rotating shifts where you have the practice of employees rotating from day to swing to graveyard shifts on a repeating cycle, I also found it difficult to quantify what percentage of the total work force is thus employed. Other schemes involve split shifts, relief shifts and the like, once again finding it equally difficult to find percentages.

I think I must also note that there is a growing trend toward alternate work schedules within the fixed shift assignment scheme, things such as flex time, compressed work weeks, permanent part-time employment, examples of which are very easy to find among office workers, but in general, in my opinion, not found very much at all among blue collar factory workers.

In general, industry's position regarding the adoption of alternate work schedules does appear to be positive. In fact, workers' happiness and the concern over employee job satisfaction are receiving increasing attention, but the prime determinant beyond that is whether the work assigned to an employee can be completed with little or no impact on the rest of the operation or the organization.

It is my opinion that with relatively few exceptions industry planners and schedulers know very little about research findings, and particularly those which might benefit them directly.

The last point which I want to address concerns the practice of rotating shifts. I think there are very few managers who do not understand that it is undesirable to have employees rotate shifts, either from a health, social, or perhaps to a lesser extent human performance point of view. Nevertheless, it is generally viewed as the only alternative for organizations producing 24 hours a day, 7 days a week.

In all fairness, there doesn't seem to be any simple solution, however. A great deal depends on the individual, the work place environment, and the tasks which must be performed.

The argument most often used in favor of rotating shifts is the tendency, due to seniority preference schemes, for the younger, less experienced workers to become concentrated on the afternoon and the night shifts. This tendency, however, seems to be dependent also on the work to be performed and the working conditions existing, such as temperature, light, degree of supervision, and so on.

In one case with which I am familiar the workers tend to gravitate to the shift best suited to them. Therefore, in this particular industry, rotating shifts are not needed or used. In another case, also involving continuous operation, there is a definite preference for the day shift, in which case management has opted for a rotating shift scheme.

In conclusion, as I have mentioned already, every job is different and every employee is different. I am not certain to what end these hearings are directed. However, I suspect it is to piece together enough evidence to facilitate decisionmaking regarding future research possibilities and the dissemination of research results.

It appears to me that a gap exists insofar as the circadian rhythm research directed at the American worker is concerned. This gap is created by the very specialized nature of each proposed research endeavor and the almost total absence of a readily retrievable data base on industry practices versus job classifications and conditions.

It also appears to me that this gap will continue to be felt in a way which impedes the dissemination of usable research results to the people who can most benefit by them, and perhaps hindering also the establishment of the best set of research priorities for the future.

If I were to be asked to make a recommendation, it would be for applications-oriented research.

That concludes my remarks.

[The prepared statement of Dr. Ward follows:]

# INDUSTRIAL SHIFT WORK SCHEDULING: CURRENT PRACTICE

Testimony Prepared for Hearings Before the
Investigation and Oversight Subcommittee of the
Committee on Science and Technology
U. S. House of Representatives

by

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# INDUSTRIAL SHIFT WORK SCHEDULING: CURRENT PRACTICE

by

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Evidence compiled by a remarkable number of individuals studying the physiological phenomena termed circadian rhythms indicates that there is a decided trend in the United States toward more night and shiftwork [1, 1980, 2, 1979, 3, 1981, 4, 1977, 5, 1977]. It is this trend, and moreso the significant impacts which circadian rhythms have on the health and welfare of persons required to work such schedules, that attracts the attention of these researchers. Moreover, it is the need to piece together the vast variety of research and scientific evidence in a way which will facilitate decision making and the implementation of results which has presumably led to these hearings. In this regard, it is perhaps significant to note my surprise, as one concerned with the issues of production planning and control, at the discovery of the vast amount of literature actually devoted to the consequences of night and shift work. I risk exposing my ignorance on being so open, but feel to the contrary that my testimony underscores the significance of these hearings.

The prevalence of night and shiftwork in the U. S. is difficult to pin down with any degree of accuracy. However, if recent statistics reported by the Department of Labor are a reasonable indicator, 26.8% of the American work force is involved in shift work, with a growth rate in major metropolitan areas of six percent (6%) per decade [3, 1981]. These are average figures, as the percentages of the total work force in certain sectors of the economy are approaching fifty percent (50%).

Statistics on the types of shift work, for example the percentage of the total industrial work force employed in rotating shift work, is even harder to document. In fact, I can do little more than state that while the practice of rotating shifts is probably not a dominant mode of scheduling in the U. S., it is, nevertheless, a significant one. I will return to the subject of rotating shifts later.

From a production planning point of view, decisions to move into a second and third shift of operation are governed by several factors, among those being: (1) increased demand for the goods being produced coupled with existing plant capacity; (2) the need to maximize the utilization of expensive or capital intensive production resources; and (3) the characteristics of the production process. To illustrate the latter, certain processes, such as those found in petroleum and some chemical plants, must simply be kept running. In other cases, while it might be possible to shut down, the lost time or the degradation in the quality of the product, due to the shutdown and startup operations, is so great that it is economically not feasible to do so.

Although there has been nearly as much research published on the topic of production planning and methods for arriving at least cost plans as there has been published results of biological rhythms research [6, 1981], the health, safety, social, and performance issues raised by the latter do not explicitly appear in the production cost model formulations. The factors and associated costs typically considered are those of hiring, layoffs, working overtime, subcontracting of the extra work, the banking of excess production from slack periods in order to cover subsequent peak periods, and the option of permitting back orders to accumulate during peak periods which can eventually be covered during subsequent slack periods. I am only aware of one research effort aimed at disentangling the complex relationship between production, economics, and shift work scheduling [7, 1964]. It stands apart as a fairly theoretical study, but no doubt presents a good frame of reference for any future work which might be considered.

Special attention must be given at this point to the need to maximize the utilzation of expensive production resources, particularly in view of the current trend towards high technology and automation invading the manufacturing work place. The recent history of a linear growth in the use of shift work is likely going to be transformed, as a result of increased automation, into a more accelerated growth pattern. The consequences, however, of these so-called "factories of the future," in terms of the percentage of the work force employed on night shifts, is likely to be a reversal of current trends. Various individuals, among those being Leontief [8, 1982], have addressed the impact of automation on the average American worker, but none, to my knowledge, have tied this in with the concerns of this committee. It is a subject perhaps worthy of investigation, insofar as there is a natural tendency to extrapolate results of research studies to a population of individuals potentially being impacted.

As I mentioned, whether to work one, two, or three shifts is often a matter of market demand and production economics. How industry implements worker shift assignments is yet another matter which varies considerably, depending on the industry. The most common scheme is the fixed shift arrangement, where a worker is assigned more or less permanently to the day shift, evening or swing shift, or night shift (graveyard shift). I say this based on my general knowledge, but at the same time state that I know of no hard evidence which can serve to quantify the claim of "most common." Tasto and Colligan [5, 1977], after a very extensive search, similarly reported an inability to quantify the percentage of workers employed under different shift assignment schemes.

Rotating shifts, employed by some industries, is the practice of having employees rotate from day to swing to graveyard on a repeating cycle. There are many variants of this, generally distinguished by the length of time on each shift. One variant is where the worker only works two of the three shifts, changing weekly, a practice which is termed oscillating shifts by some.

Other schemes involve split shifts, such as are commonly found in the public transit field, and relief shifts. Split shifts are characterized by gaps of unworked time, often of considerable duration, between two or more duty assignments on the same day. The contractual conditions governing the assignment of workers to split shifts are typically very complex. The usual cause of split shifts are conditions resulting in two peaks in demand (output) occurring within the same day.

Relief shifts are created by the absence, illness, or time off of regular employees. The nature of the relief shift assignment is a function of the specific scheme employed for the regular workers.

One must also note that there is a growing trend toward alternate work schedules within the fixed shift assignment scheme. Nolan and Martin [9, 1978], and more recently Lieb, Lefkowitz, and Associates [10, 1981], have documented both the practices and the trends. The most common practices, again with considerable variation within each one, are "flexitime," "compressed workweek," and "permanent part-time employment."

In flexitime, employees may vary their starting and stopping time within limits, as long as they work the contracted number of hours in a specified time period (day, week, or month). In a compressed workweek, the usual number of weekly full-time hours is compressed into fewer than five days, thus permitting longer breaks or weekends. Permanent part-time employment is equivalent to regular voluntary employment (not temporary or casual) which is carried out during working hours distinctly shorter than normal. The practice of staggered start and finish times and the task assignment (free to leave when completed) schemes are also worthy of note.

In general, industries' position regarding the adoption of alternate work schedules appears to be positive. Worker happiness and the concern over employee job satisfaction are receiving increasing attention today. The prime determinant beyond that is whether the work assigned to an employee can be completed with little or no impact on the rest of the organization. There are, no doubt, incidences of economic considerations given to indirect premiums paid for compressed workweeks, but the extent to which they are systematically weighed against the effects of circadian rhythms is probably rare.

The last point I want to address concerns the practice of employing rotating shifts. I feel very comfortable in stating that there are very few managers who do not understand that it is undesirable to have employees rotate shifts, either from a health, social, and to a lesser extent human performance point of view. Nevertheless, it is generally viewed as the only alternative for organizations producing twenty-four (24) hours a day, seven (7) days a week. I have little doubt that it would be rare to discover a case where management has made a determined and systematic evaluation of the economic alternatives (vis-a-vis the imputed cost of lost productivity, worker turnover, absenteeism, illness, and the like) and the wage differentials which might be negotiated to make an alternative arrangement more acceptable to management and worker alike. In all fairness, however, there are no simplistic solutions. The consequences of rotating shifts, or even shift work in general, in view of the implication of circadian rhythms, depend greatly on the individual, the work place environment, and the tasks which must be performed.

The argument most often used in favor of rotating shifts is the tendency, due to seniority preference schemes, for the younger, less experienced workers to become concentrated on the swing and, to a much greater extent, graveyard shifts. This tendency, too, depends on the work to be performed and the working conditions, vis-a-vis, temperature, light, degree of supervision, etc.

I will conclude this testimony by reflecting on some cases with which I am most familiar, which should leave the impression quite clearly that there is a great deal of variation in practice.

In one case involving a manufacturer of food, where around-the-clock operation is the rule, management recognizes that rotating shifts, despite the existence of a seniority selection process, is more problematical than fixed shifts. Indeed, the latter is in force. Moreover, this industry has observed that the workers tend to gravitate to the shift best suited to them. I believe that rhythm researchers recognize that there are "day people" and there are "night people." In this industry's experience, senior people are found on all shifts via the process of natural selection.

In another case, also an around-the-clock food producer, even when the company moves to seven (7) operating days a week during peak seasonal periods, they choose to pay time-and-a-half for overtime, as opposed to the use of rotating shifts, because of anticipated "employee problems." However, even in this case, it is doubtful as to whether any detailed economic calculation is made regarding the optimal length of time they can afford to stay on overtime in view of the costs implied by the rotating shifts.

In yet another case, a primary metals producer, the tendency, because of a seniority selection process, for the lesser experienced persons to be on the night hour shifts is much stronger. Hence, management has opted for a rotating shift scheme which cycles every 28 days. An example is:

| Shift | Work | For | Off |
|---|---|---|---|
| Day | Tuesday to Monday | 7 days | Following Tuesday & Wednesday |
| Swing | Thursday to Wednesday | 7 days | Following Thursday & Friday |
| Graveyard | Saturday to Friday (8am) | 7 days | 8am Friday to 8am Tuesday |
| Repeat cycle | | | |

Supervisors will work the same schedule, and maintenance a similar one, but staggered. In some plants, where the seniority practice is very strong, a mix of fixed and rotating shifts is found, because the "most senior" people can select a fixed shift. Because of the extreme difficulty in scheduling which results, the need for a "shift hopper" surfaces. This person(s) will hop from shift to shift, typically every two days, or as needed to fill in the gaps.

In the last case, a metal fabricator, it was found that the equipment (process) works best when you keep it running. Even the simple shift change brings about some interruption and results in lost quality, production, or both. As a result, employees and management together conceived extended hour shifts which would overlap by one and a half (1 1/2) hours. Since forty (40) hours were still worked, it resulted in longer weekends every week, which in turn resulted in a marked improvement in employee morale, to say nothing of the improved productivity.

In conclusion, every industry is different, every job is different, every employee is different. It appears to me that a gap exists insofar as the circadian rhythm research which is directed at the American worker in industry is concerned. This gap is created by the very specialized nature of each proposed research endeavor and the almost total absence of a readily retrievable data base on industry practices vs job classifications and conditions. It also appears to me that this gap will continue to be felt in: (1) impeding the dissemination of usable research results to the people who can most benefit by them; and (2) hindering the establishment of the best set of research priorities for the future.

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Mr. GORE. Thank you very much. I find both statements quite helpful.

Mr. Zalusky, what kinds of studies would you recommend be done by NIOSH? Can you be specific?

Mr. ZALUSKY. We would like to see studies that would give labor and management some sort of insight as to what is the best type of shift design in a given type of community in a given type of work setting in a given type of industry; which type of rotating shift; if there are going to be rotating shifts, how long the rotation cycle should run, and what the relative impact of doing it one way versus another way would be.

As Dr. Ward pointed out, the way it is operating right now everybody is just simply trying different things on and there is no communication between one organization and another. There is no synthesizing of this data.

We do know that the social impacts on the worker are somewhat different in a community that is accustomed to shift work than they are when a person is unique within community because of the shift schedule. We know that some occupations that are physically demanding require more rest and time between shifts than others.

The integration of this information in a fashion that permits strategies for labor and management is just simply lacking.

Mr. GORE. It seemed to me when we were first planning this hearing, and it has seemed to me through the first day and through your testimony, that this is not an issue that ought to produce any conflict between labor and management.

Mr. ZALUSKY. I shouldn't think so.

Mr. GORE. It is an issue in which both sides have the same interest because productivity and job satisfaction go hand in hand.

It also seems to me that it would make a lot of sense for both labor and management to take this latest circadian rhythm research into account in designing shift rotation schedules. Specifically, schedules rotate forward instead of backward, and should allow sufficient time between shift changes to allow the body clocks to catch up and adjust.

Dr. Ward, do those statements seem sensible to you or not?

Dr. WARD. They definitely seem sensible to me. As I indicated, however, I think there are very few planners and schedulers who are aware of the work that could possibly potentially benefit them or their industries. There has to be some effort at drawing the vast variety of work that has been done together in some meaningful way.

I think that before proceeding into the future with other possible research efforts there has to be some attempt at establishing priorities, finding out where the problems are the greatest in terms of health and safety performance, and social as well.

Until that is done, it is going to be a very difficult problem. I think it has to be addressed.

Mr. GORE. We hope to pull that together in a report that will come after these hearings. We hope to disseminate that report widely. We hope that it will be helpful.

It seems that the problems of shift work are currently treated as necessary evils that are compensated with higher pay. Is that a fair statement, Dr. Ward?

Dr. WARD. They are generally compensated with higher pay. A shift differential is generally paid, and the amount of that differential varies considerably, depending upon the industry and the work that has to be performed. Yes, it is a fair statement.

Mr. GORE. Mr. Zalusky, from the point of view of the labor force, what can be done to increase awareness among workers in this country of the benefits of the scientifically designed shift rotation systems? Do you have any suggestions there?

Dr. ZALUSKY. We have published in the Federation—that is the article I did in 1977 that you have a copy of, and the machinists did a similar study—that most unions do circulate memoranda to their field staff to try to advise them on some of these things as they occur.

I think one of the areas of uncertainty that is beginning to bother a lot of people in unions, in terms of representing their membership, is the shift from blue coller occupations that were historically male, to those that are more clerical or service type and their use of rotating shifts or fixed shifts and the effect that that will have on women with dependent children. This is the sort of a problem that we really haven't looked at. It has been more of a male problem with shift work than female. We are beginning to deal with the social concerns of women working shifts and the effect on family life.

Mr. GORE. Dr. Ward, what are some of the institutional factors or economic factors involved here? We have heard that the need to make maximum usage of capital intensive equipment pushes toward the use of three shifts. That is relatively obvious, and no one can quarrel with that.

I am wondering, when a factory has a choice between a weekly rotation of shifts or a monthly rotation of shifts, are there any factors from the management or labor standpoint that push toward shorter rotation time?

Dr. WARD. One that comes to mind would be the factor of the so-called learning curve or experience curve. Very often when you change shift you may also get involved in different activities on the different shifts. The amount of time it takes to come up to speed after that change has occurred can affect decisionmaking.

If it takes quite a while to come up to speed, to come down on the learning curve, so to speak, you would want to benefit from that as long as possible, in which case a longer duration or longer cycle would be involved.

Mr. GORE. That pushes in the direction of a longer rotation interval.

Dr. WARD. Yes, it does.

Mr. GORE. A longer rotation interval is superior from the standpoint of circadian rhythm adjustment. Yet, so many factories and other operations employ a weekly rotation schedule.

I am wondering what institutional or economic factors might push in that direction? You have identified one that pushes in the other direction. It may be that the answer to the question is that there aren't any significant ones and that it is really sort of force of habit. Perhaps the graveyard shift is viewed as so unattractive that the best way to handle it seems to be to get people out of it as soon as possible. The weekly rotation may make it seem more endurable, whereas in fact the effect on the body clocks is worsened by the shorter interval.

Europeans, I am told, tend to use a very rapid rotation schedule—a 1- or 2-day rotation schedule. Mr. Zalusky, are you familiar with that practice?

Mr. **Zalusky**. Yes. As a matter of fact, the French in the late seventies considered making severe statutory limitations on shift work. One of the things that did come out of that was the use of a greater number of shift crews, rotating, so that when they rotated on to the night shift, they would stay on there 2 or 3 days and then rotate off it very quickly, so that period of time on that shift was more like a toot on the town than a change in body and social patterns.

That has been some of the work that has been done, but as I mentioned before, there has been no real integration of this knowledge and what the effects of it are so that we get a sense of practical application here in the United States.

What may work in some settings may not work in others, as Dr. Ward pointed out. The police, for example, require unique scheduling. The learning curve is unique, the informants that are available and the people that are on the street are different for each shift. As a result the police forces normally keep people on a rotating shift, but the rotation period runs 6 months rather than changing every week or so.

Mr. **Gore**. Thank you.

Congressman Reid.

Mr. **Reid**. Mr. Chairman, I think you have covered most of the questions that I had.

Dr. Ward, I am particularly interested in one thing that I read in your testimony. You wrote about factories of the future in which you expect a reversal of current trends in terms of night shift work.

What did you mean by that? Is there going to be more or less demand for 24-hour operation?

Dr. **Ward**. I was referring in this case in my prepared testimony that there wouldn't be a decrease in work taking place in the nighttime, but perhaps in the industries which are going to become more automated, that there will be less call for labor being required at those times. There are a number of plants that exist where you have almost total automation during those particular shifts.

In preparing my testimony, I was trying to quantify some of these trends and percentages. I did find it very difficult to do. I included that in my testimony to indicate that perhaps in some industries—and I can't say what percentage of the work force that that is going to involve—that rather than an increasing trend toward more and more shift work, that you will find the reversal because of increased automation.

Mr. **Reid**. Dr. Ward, would you tell me, if our roles were reversed and you were going out to Las Vegas to meet some of your constituents and they asked you what you did this week and you said, "Well, I sat through hearings most of the week dealing with jet lag and shift work." Of what importance would you say this is to the public?

Dr. **Ward**. I think it is very important because there are an awful lot of people in a variety of occupations that have experienced this and know the consequences.

I was relating to Mr. Zalusky right before we started that. I have experienced working on different shifts and it is something that I personally would not want to go back to. I think it is important.

Mr. **Reid**. Important, OK, but why?

Dr. **Ward**. It is important in terms of all the factors which have been raised: In terms of people's mental well being; in terms of their health; and in terms of their ability to live a normal life, like a lot of other people, with their families and their community.

Mr. **Reid**. Would it be a fair statement, Dr. Ward, to say that for years and years and years we have many people on shift work, but no one really understanding or has even been thinking about the consequences of what it does to people's lives?

Dr. **Ward**. Currently I think there is a lot of awareness of the importance, but people just do not understand or know exactly what the consequences are. It is my feeling, as I mentioned in my testimony, there are very few managers who do not understand the problems of rotating shifts in particular.

Mr. **Reid**. Did I understand you to say there is a lot of work going on but that nothing that has brought it all together?

Dr. **Ward**. It seems to me that that is true. The people who are making the decisions don't have those facts.

Mr. **Reid**. Thank you very much, Mr. Chairman. I have nothing further.

Mr. **Gore**. Thank you.

Congressman Durbin?

Mr. **Durbin**. I apologize for coming in late. Unfortunately the shifts around here are not always coordinated. At times we work double shifts with no overtime, I might add.

I am led to believe by some people I have spoken to, particularly in the labor movement, that one of the considerations that is moving us more toward night work is utility prices, where in some instances the company finds it a lot cheaper to run their factory at night at a lower utility pricing.

I don't know if you covered this in your testimony, but are you running into that?

Mr. **Zalusky**. Yes, we do run into that. There are a couple of factors, in addition to the utility pricing. We were talking a moment ago about different types of work that are going onto more shift work.

Utility pricing, where they have the nighttime reduced rates, tends to encourage that usage of shift work. We noticed that in two settings in Wisconsin when Wisconsin Power & Light went to a reduced rate for industrial users during nonpeak hours.

Interest rates are also causing a movement toward shift work. That sounds a little peculiar, but high cost of capital is a factor. The Three Mile Island repair job, when they were doing the cleanup and repair, the construction workers went to shift work around the clock. Ten hours a day, 4 days a week, to get maximum utilization of daylight hours; and continual 7 day coverage.

So, we are beginning to see some of this on jobs that require an awful lot of capital investment, the use of shift workers. We see it developing more in the clerical occupations than we did in the past because of the high cost and rapid ???? computer operations.

As I mentioned before, we seem to feel this has an impact on single women, heads of household and single parents generally, who have families at home with babysitting problems and that sort of thing.

So, we do see shift work growing and we do have a good deal of concern about it. We, as Dr. Ward pointed out and I think I did before, lack the knowledge of being able to integrate the scientific work on biopatterns and community relations, on the economic consequences of various shiftwork options. That is, we are looking for and hope to get as a product of this committee, direction in this area so that we can implement the most effective shift work systems.

Mr. **Durbin**. After the late 1800's and for several decades, the industrial worker lived with 6-day and 7-day weeks. Then I suppose in the thirties there was a real movement toward a 5-day week. You hear a lot of talk about a 4-day week with 10 hours a day and the like.

Did anyone do any studies in that transition period in the thirties—I believe it was in the thirties—when we really started seeing more prevalent use of the 5-day work week in terms of productivity or the impact on workers' lives?

Mr. **Zalusky**. I don't think we have a systematic type of study. Some of the earlier studies on shift work dealt with railroads, around the turn of the century, and they centered more on the problems of social isolation of shift workers of the latter studies. Some dealt with the worker's ability in motor coordination and so on. After that a lot of the research on shift work centered on our military establishment in terms of the flight crews, of Strategic Air Command aircraft. Productivity of the workers themselves really wasn't dealt at the time.

In the thirties, when we went to a shorter workweek, it was more of a work sharing concept than it was a productivity concept, making more jobs available in a depressed economy.

Mr. **Durbin**. What are your thoughts on the 4-day workweek with 10 hours a day, for example?

Mr. **Zalusky**. I think a shorter workweek would create a lot more jobs and employment in this country, something we should be considering very seriously.

Mr. **Durbin**. Is there any study being done now as to productivity questions, whether you can generate enough work in 10 hours 4 days a week as you do in 8 hours 5 days a week?

Mr. **Zalusky**. One of the problems we look at in terms of productivity is we look at the number of units produced by $x$ number of workers that are gainfully employed. We fail to look at the loss productivity of the unemployed, our wasted capital, in a way. Once a person is unemployed and that person's work is lost, we don't count it in our arithmetic on productivity. That effort can never be recovered.

So, to really utilize our human capital we think we have to go to a 4-day workweek.

Mr. **Durbin**. Thank you.

Mr. **Gore**. Thank you very much.

I would like to thank both of you for your contribution here today. I hope we can come up with the kind of work product that will be of use to you. We will be back in touch with you.

Thank you very much for helping us out.

Mr. GORE. Our second panel is made up of Dr. Harvey Goldstein, director of psychological services at the Prince George's County Police Department in Upper Marlboro, Md.; Dr. Gary LeClercq, medical director with Exxon Chemical Americas in Houston, Tex., accompanied by Dr. Gary Krieger, the Baytown area medical director with Exxon; and Dr. Charles F. Ehret, senior scientist with the Division of Biological and Medical Research at the Argonne National Laboratory in Argonne, Ill.

I would like to welcome all of you to this hearing. We are delighted to have you here. Without objection your prepared statements will be included in the record.

Dr. Goldstein, if you would lead off. We are delighted to have you with us. Please proceed.

[The biographical sketch of Dr. Goldstein follows:]

### HARVEY A. GOLDSTEIN, PH. D.

For the past two and a half years Dr. Harvey Goldstein has served as Director of the Psychological Services Unit of the Prince George's County Police Department. Prince George's County is a jurisdiction of approximately 700,000 people and listed as the 59th largest law enforcement agency in the country.

In that time Dr. Goldstein has been instrumental in:

1. Creating the Law Enforcement Behavioral Sciences Association, a regional consortium of mental health practitioners for metropolitan police agencies.
2. Organizing the first natioal network of police psychologists by starting APA Division 18's section on police psychology.
3. Authored and presented at national conferences on structural interventions in the police agency for the treatment and prevention of stress.

Dr. Goldstein is also an adjunct professor at the Johns Hopkins University.

Prior to joining Prince George's County Police Department, Dr. Goldstein served as an independent consultant to Fortune 500 industries, organizations and public service institutions, as well as his own private practice. Prior to that he was a research associate at the American University investigating the psychophysiological effects of stress on adult learning and adult development. Dr. Goldstein is a clinical psychologist with a Ph. D. from American University specializing in learning and behavioral disorders.

## STATEMENTS OF HARVEY GOLDSTEIN, DIRECTOR, PSYCHOLOGICAL SERVICES, PRINCE GEORGES COUNTY POLICE DEPARTMENT, UPPER MARLBORO, MD.; GARY R. LeCLERCQ, MEDICAL DIRECTOR, EXXON CHEMICAL AMERICAS, ACCOMPANIED BY GARY KRIEGER, BAYTOWN AREA MEDICAL DIRECTOR; AND CHARLES F. EHRET, SENIOR SCIENTIST, DIVISION OF BIOLOGICAL AND MEDICAL RESEARCH, ARGONNE NATIONAL LABORATORY, ARGONNE, ILL.

Dr. GOLDSTEIN. It is a pleasure to be here.

Let me first apologize for some of the typographical errors in my written testimony. It was dictated and we didn't have a chance to proofread it before we left our office last week. So, I do want to apologize for that.

Let me start by saying that there is no doubt in my mind that you are going to see that there is compelling evidence that the effects of shift rotation and night work are highly detrimental to health, particularly in law enforcement. I will speak specifically to that. (Please refer to submitted written testimony.)

Because I don't want to be redundant, and there are people here far more qualified than I to speak to the technical aspects of laboratory studies, let me focus specifically on law enforcement and some of my observations of what has occurred.

It is the contention of myself and my colleague, Paul O'Neill, who has just recently designed a shift study for Prince Georges County police, that the lifestyle, the life mode of law enforcement in general in this country is highly influenced by shift work, also in a highly detrimental fashion.

It is our belief that we are seeing repercussions in the highly disproportionate statistics of health problems in the police population. The implications and impact on the public and the citizens, communities hasn't come close to being measured as of yet.

Specifically, around the health problems that we see, that we attribute in at least in some way, shape, or form to shift work, on such repercussion is the high alcoholism rate. What does shift work have to do with alcoholism.

We see it as a self-medication process where people, trying to compensate for not being awake during times when they know that they should, ingest high amounts of caffeine. Later, when they feel they need to be asleep, they are ingesting high amounts of alcohol to calm their system. Of course, they are not getting anabolic sleep, they are not getting that good restorative sleep.

Remember, we are looking at people who we are putting out on the streets, with guns on their hips, trying to make split second decisions. The very qualities that we want most exhibited by police officers are those that are diminished by rotating shift work. The qualities we are talking about include vigilance, speed, accuracy, decisionmaking, reasoning, and judgment. These are all impacted upon by rotational shift work.

It is also my contention, and I don't have specific data yet to back this up, that some of the family and social aspects that were spoken to before by the other two panelists are also occurring at a high rate in the police department. (Social isolation—alienation.)

I don't need to speak to you about high divorce rates. In the police agency it is a well-known statistic. In terms of domestic violence—we are getting in many reports of things such as wife battering, spouse battering, and high degrees of explosive behavior, which seem to be following certain kinds of shift rotations; for instance, coming off midnight in the three rotational pattern onto day work.

Anecdotally, we get a lot of reports from spouses of police officers who believe that they can't go near their husbands, that they are just "bears". The personality changes are marked, and often children cannot approach their father during that particular shift.

One of the things that I need to mention with regard to a point that was made earlier by the other two panelists is this labor and management issue. I don't think it is quite as easy as saying, "Hey, we all realize that this is a problem, and therefore shouldn't we make this nice for everybody, that you will be healthier and it will be more cost effective for us".

There are deeply ingrained and resistant patterns of behavior on the parts of institutions to move toward examining these problems. Tradition bound institutions, such as law enforcement agencies—Paul O'Neill tells me he got this one directly from Dr. Weitzman at Cornell Medical Center, who was hired to work with New York police, to help with their cooping problem (police officers falling asleep during the job). The agency did not want to fire these police officers so they said, come in and help us work out a shift plan.

Well, the union was not amenable to this kind of change because it impacts on a lot of other things. In some cases it is things such as part-time work. The political climates need to be addressed. The ingrained social patterns need to be looked at. So, labor and management coming together on this is a problem.

One of the things that is forcing the issue, however, is civil litigation. We are starting to link together the relationship of police officers who are going out on heart attacks and strokes that have been associated with hypertension, and hypertension to the stress of shift work.

I will tell you right now, we just had one recently, and there is a tremendous uproar about this because people are going out on job-related disabilities. They are worrying about their retirement system crumbling because of so many police officers who can point to shift work as one of the major factors that have precipitated things such as heart attacks and strokes.

One of the studies that was done, a minor study in our own department—we were on a 7-day shift plan at one point, 7 days on, 2 days off, 7 days on, 3 days off. They found in the fifth, sixth, and seventh days of those shifts that excessive force complaints were increased dramatically. We are finding that departmental car accidents increase in certain patterns on our current shift plan.

The implications, I think, are clear. How many police officers are in fact initiating assaults because of their low frustration tolerance, high irritability, and tendency toward aggressive behavior as a result of not being able to tolerate or adapt to shift work?

My own observation is that longevity has to be impacted upon. One of the major statistics in police work has to do with early death after retirement. There is an alarming number here that 3 to 8 years after police retirement, 50 percent of the population is dead. That is an alarming statistic.

One of the speculations is that 20 years of shift work contributed greatly to the lifestyle and pattern. I am not saying it is shift work per se, but it is the pattern that is induced, that self-medicating pattern, the social isolation that is caused as a result of it. We need to do whatever we can to minimize these kinds of impacts.

One of the things that I think is most important to take a look at are some of the guidelines that we might use to minimize the deleterious effects that we are seeing. I think some of Dr. Ehret's work is something that needs to be field tested, something that we need to have out there in the law enforcement community, workshops on adaptation.

There is pressure, because of litigation, around the whole idea of psychologically unfit police officers. This is something recently seen in major lawsuits in New York and Washington, D.C. Police officers, who are "losing it" out there, are being held liable later in court for excessive force complaints. A lot of the acts that they are peforming seem out of character with their normal behavior.

I see a great deal of "burnout" in police officers, young men as well as old. I would like to give you another little example of that.

A 44-year-old state trooper, who saw me privately, spent 13 years in the evidence section working only a two-shift rotation. He had to leave the evidence section because of a lot of reasons, but he was put back on a three-shift rotation.

He could not stay awake during the night rotation. He would get 14 to 16 hours of sleep prior to it, and he could not keep awake. His body just literally could not adapt. He needed to retire from the state police.

Now, the state police want to fire him. They are saying, "Well, if you can't do the job then you are going to have to leave." He, is going to be tied up in the courts for a while.

These are the kinds of things that are happening. There is no doubt in my mind that what we are talking about is that lifestyle in fact is a pathogen. We are going to need to start to integrate and field test some of the research so that we take a look at how this affects immunology, neurology, psychological factors, and epidemiology. There is just a whole array of things that need to be tested out.

We do need the guidelines. Unfortunately the impetus is not going to come from the institutions themselves. From my point of view, there is institutional complicity in the early death of police officers and a lot of unhealthy things happening out there in the community. Because I see it every day—I have a tremendous caseload, and my office sees a lot of police officers—it is clear to me we need to test it out and prove it.

We have initiated a shift plan study after 2½ years of battling with our administration and the union. It was ironic that the union again, when we first proposed it, said you are violating a condition of work stipulated in our contract. You want to throw your hands up in the air.

He said, "We are going to sue you if you try this test plan." We said, "You ought to be suing the department for making you work it." So, it is really ironic. What is most ironic is that the public safety sector, the area that affects all of us so much, is the last to get the behavioral technology that we need to support public servants.

Again, the No. 1 hedge against stress in general is a social support system. That is, again, what is most diminished by this kind of rotational shift work.

What I would propose, as we are doing now in this particular study that Paul O'Neill is mainly responsible for designing, is that we start taking a look at the family variables, personality variables, as reported by supervisors, decreases in departmental accidents, and the number of assaults that go down.

If you are in the police culture, you know that a police officer can initiate assault very easily. We are starting to feel that some of the high irritability and low frustration tolerance that goes along with this shift work is a major factor in assaults on police officers, because they have less tolerance for a situation.

If there are other questions that you have later, on the specifics of the study, we would be happy to answer them. I think that is kind of the bottom line.

Thank you.

[The prepared statement of Dr. Goldstein follows:]

# Subcommittee on Investigations
# and
# Oversight Witness

## Administrative Information

Prepared By

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March 16, 1983

It has become exceedingly unhealthy to be a police officer in modern society. The unhealthfulness of police work is not so much related to the obvious life and death potential faced on each call as it is the myriad of interacting variables (see Appendix 1). The disproportionate disabilities and incidents of health problems have implications extending beyond the police population. As a behavioral scientist who works with a police agency and is privy to information from agencies from around the country, the observational data, anecdotal reports, and clinical data collected suggest without question that this population is immersed in a life style that is clearly deleterious to their health and has impact on the citizenery and communities in which they serve. Perhaps the most compelling argument is that a police agency and its personnel deals with the greatest degree of human deviance, the broadest range of crises in the human condition, and the most sensitive and labile of situations in community and society. Yet, law enforcement agencies are seemingly the last to acquire the behavioral technology that they need for support of their personnel. The seeming insouciance of public service institutions seems to only be mitigated by the legal decisions governing liability and negligence.

A major variable that has had impact on all the other specific stressors related to the nature of police work is the "temporal misfit between people and their environment as can be observed in the altered rest/activity patterns required from shift workers." There is convincing evidence that night work and work on rotating shifts disrupts the biological rhythms and interferes with physiological mechanisms. Thus, accuracy will decrease, time of work operations is extended, and fatigue is increased. Shift work appears in virtually all literature on police stress as a contributor to the job specific stress of law enforcement. The mention of shift work as a stressor is usually listed along with thirty to fifty other stressors that contribute to the high incidents on health indices of the police population. It is very symbolic of the scant attention paid to what appears to be emmerging as a pervasive life shaping pattern. Police agencies are tradition bond institutions. Their assignment to and design of rotating shifts is organized with little regard to the health of the police officer. There are many sociocultural and organizational reasons for this approach. Perhaps the most salient is that in an agency where machismo governs much of the cultural norms, complaints about a "schedule" would not be consistent with the perceived image, both inside and outside the department.

Nonetheless, the majority of jobs with the police department are routine patrol functions that necessitate shift work. With mandatory night work ingrained in the history of modern police work, the tolerance and adaptation problems have been viewed as a necessary requirement for the job. Most shift plans are developed with major emphasis on maximum police coverage during peak crime periods. There is little or no thought to social, psychological or physiological impact on the individual patrol officer and consequently his family and community.

It is the consensus among researchers that officers report physiological adaptation problems in readjusting to eating and sleeping patterns as their hours of work rotate. Virtually all the research would suggest that police officers are suffering from signs of chronic mental fatigue. Fatigue is directly attributed to shift schedules and the social psychological sleeping and eating patterns and physiological disruption associated with night work. Researchers of night and rotating shift work generally focus on changes and the quality and quantity of production, absenteeism, tardiness, accident rates, deep body temperature, and self-reported sleeping patterns and stress related physiological symptoms. Rationale for utilizing this criteria is the degree of adaptation to night and rotating shift work can be inferred from these indicators. There has been virtually no research in settings of public safety agencies as to the possible consequences of the previously mentioned psychological and physiological manifestations of disrupted circadian rhythms on issues such as excessive force, departmental car accidents, inaccuracy in shooting incidents, inability to effectively respond to domestic violence situations, or increases of assaults initiated by police officers.

The results of our own departmental survey and surveys of police agencies around the country clearly point to symptoms exhibited by individuals that are associated with circadian disruption. The ramifications of desynchronized or disrupted circadian rhythms on law enforcement and other safety oriented occupations is particularly distressing. Researchers agree that in the case of continuous three shift work schedules that rhythm disturbances are unavoidable. The most important thing is to secure a long continuous rest time after relatively short period of night work to minimize and make up for sleep deficits. One of the only studies that actually examined an aspect of shift work in a police department discovered a significant and direct and positive correlation between the sequential number of nights worked and allegations of police brutality. The research and study of circadian disruption in law enforcement settings is tantamount to providing the public with safeguards against psychologically unfit police officers. Currently the courts have directed (by virtue of their decisions in a number of civil suits) that police agencies have a workable program to identify psychologically unfit police officers. These court decisions came about from complaints by members of police families against the agency for radical personality changes that have resulted in such things as wife battering, chronic alcoholism, explosive behavior, and child abuse cases with the police agency as precursor to violent acts outside the agency.

The implications of the data you will be hearing on disruption of circadian rhythms and its manifestations, particularly in the law enforcement area, are clear. The institutional laxness and strong resistence to provide the available behavioral technology to minimize the effects of both the short and long term problems associated with shift work in law enforcement is complex. Imagine that we are hiring public service personnel to respond with a split second decision in high stress situations with a deadly weapon with judgement, reasoning, and accuracy in light of the debilatating effects of night and rotating work. It is also important to note that the very supports that are most beneficial for dealing with stress of any kind, specifically the social support system of an individual, is hampered by rotating shifts. For instance, research clearly suggests that friends and relatives outside the work place, most notably spouses, are important sources of support in the face of occupational stress. Thus, they can not be ignored from an implied perspective in research evaluation.

Shift work impinges directly on family functioning as well as the individual worker. Spouses and other family members may need support themselves, as well as serving as support for the worker. Similarly the interaction with groups, individuals, and acquaintances outside the police mileu have been found to reduce the stress that is associated with alienation of the police department employee. While social support is not a panacea for the problems of work related stress and health, it is an important component of a comprehensive plan to reduce work stress of both a physical and mental nature.

The longitudinal study of real life settings, such as law enforcement agencies, will further illuminate the health problem implications due to the disruption of biological rhythms. Alterations in body temperature, pulse rate, blood pressure, electroencephalograph rhythms, breathing rhythms, oxygen intake, blood cell chemical compositions, cellular metabolism and hormones dissolved in plasma, hormones dissolved in urine, sleep patterns, rheticulohypothalamic activity conceivably precipitate heart attacks, hypertension, and strokes. Public safety institutions need to provide guidelines that minimize the effects of such disruption. It is my clinical observation (there is no specific data to support this) that because of long term shift work by police personnel, that their immunological resistence to disease appears weakened, aging seems accelerated, and personality changes are characterized by low frustration tolerance, high irritability, impulsivity and agression.

Areas that have been used as criterion for defining severity of adaptation or tolerance of night work are noted below with respect to our own police department's stress survey.

1. Sleep Disruption - The disruption of sleep stages and patterns is a major contributor to emotional and physical fatigue. According to our own shift survey results, 49 percent of sampled officers reported fatigue. This fatigue adds to and in some cases produces pathological symptoms. Sleep pattern disruption is also closely related to speed of recuperation on working nights. On the average, between the third and eighth consecutive night shift sleep disruptions emerge. Thus, a longer recuperative period is needed for rotation back to night work. According to our survey 47 percent of our patrol officers sampled indicated that they have moderate to severe sleep problems. This is in contrast to an estimated 11 percent of day workers in the United States that suffer from sleep disturbances.

   Fatigue emerging from sleep disturbances is also most pronounced in workers who are performing boring routine activities or any form of mental work.

Another area used for a criterion is the report of pathological effects. These are symptoms exhibited by workers that are not adapting or tolerating night work. The physical symptoms most frequently noted are digestive disorders, most specifically dyspeptic disorders, as well as gastric and duodonal ulcers. Twenty-eight percent of sampled officers reported digestive problems. The suggestion that effects of night and shift work have impact upon the hypothalmus (that part of the brain that is instrumental in regulating sleep and arousal states, hunger, thirst, body temperature and emotions) has implications for individuals that may be suffering from diseases such as diabetes, epilepsy, high blood pressure, arythmia, and cerebral trauma. Other physical symptoms discerned from the stress survey were general anxiety, sexual dysfunction, headaches, and muscle tension. Emotional symptoms exhibited by shift workers are associated with "night workers neurosis." This includes but is not limited to general weakness, insomnia despite fatigue, and self-reported personality changes. The results of our survey support research that "night workers Neurosis" exists and seems to be present in our work population.

In terms of work performance major impairment seems most obvious during night shift. The tasks that are impaired the most seem to be mental tasks, the speed of task performance, the accuracy of the performance, vigilence and judgement. There is strong evidence that work tasks entailing strenuous physical labor are the least impaired. A number of researchers believe that work performance impairment is a combination of sleep disruption and disruption of the normal functioning of the hypothalmus.

Another area that is examined is accident rates. Although the frequency of serious accidents is higher during night work than day or evening work, the general frequency of all accidents is greater during day work than night or evening work.

Many researchers attempt to investigate health differences between shift workers and day workers by reviewing attendance records. Unfortunately, not all sick leave can be directly attributed to illness. The only conclusions that can be drawn from the research studying sick leave patterns is that workers working a rotational shift pattern tend to be absent most frequently on the first day of day work after rotating after night work.

Anecdotally, reported spouse abuse seems to occur most during the break after the night work rotation. These incidents are almost exclusively isolated to this specific period in the rotation cycle. Spouses report that there is noticeable change in temperment at those times. Alcohol abuse also appears to be related to shift cycle pattern. The abuse of alcohol in police departments appears at a maximum during evening and night work rotation and at a minimum during day work.

Perhaps the most salient conclusion to be drawn from the literature, the research, and our clinical observation of the law enforcement population involved in rotational shift work is the initiation and reinforcement of pervasive life style habits that are highly detrimental and self distructive. One aspect of this life style is the notion that tolerance to night and rotation work is somehow aided or compensated through self medication. Even those individuals who attempt to take special responsibility and care of themselves still suffer at least some degree of dysfunction. A typical self medication pattern is one characterized by massive dosages of caffeine to stimulate during periods in which the police officer needs to be awake although his body tells him he needs to be resting and then equally massive dosages of alcohol to sedate and depress the central nervous system when he knows he needs to sleep although his body is trying to keep awake. The implications that may be gleaned from the research cited above and the rest of the testimony presented is that we clearly need to have support and direction for field application and analysis of the circadian disruption is safety oriented occupations. One significant area for future study is guidelines in discerning those who would be most able to tolerate or adapt to the kind of rotation shift work that is deemed to be necessary. There is some evidence to suggest that individuals do seem to exhibit different stages of tolerance or adaptation to rotational shifts. Also, screening for age factors needs to be examined to identify duty assignments that are less risky.

Research that seeks to alleviate circadian dysfunction through dietary and sleep patterns (Dr. Ehret's work) needs active field testing. Analysis of the eugenic factors which maximize adaptation and coping are warranted.

By studying what traits, characteristics, and life style modifications are consistent with relatively health adaptation, public safety errors and individual and aggregate health stats will be reduced.

(Appendix 1)

### Table 2

### Means and Standard Deviations of the Police Stress Survey Items for the Mail Survey and Pilot Study

| | Items | Mail Survey (N=210) | | Pilot Study (N=45) | | |
|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Rank |
| 1. | Fellow officer killed in the line of duty | 89.3 | 15.2 | 86.1 | 17.3 | 1 |
| 2. | Killing someone in the line of duty | 86.9 | 19.6 | 81.5 | 23.0 | 2 |
| 3. | Exposure to battered or dead children | 79.3 | 20.1 | 78.9 | 16.6 | 3 |
| 4. | Physical attack on one's person | 74.5 | 25.2 | 74.5 | 20.5 | 5 |
| 5. | Situations requiring use of force | 71.2 | 24.9 | 70.9 | 16.5 | 6 |
| 6. | Inadequate salary | 70.2 | 25.1 | 69.2 | 19.8 | 7 |
| 7. | Inadequate support by department | 70.1 | 24.2 | 67.7 | 18.0 | 10 |
| 8. | Confrontations with aggressive crowds | 70.0 | 23.7 | 75.8 | 16.0 | 4 |
| 9. | Ineffectiveness of the judicial system | 67.0 | 24.0 | 59.4 | 23.7 | 21.5 |
| 10. | Inadequate support by supervisor | 66.4 | 23.1 | 68.0 | 20.0 | 9 |
| 11. | Plea bargaining and technical rulings | 66.2 | 22.2 | 57.2 | 21.5 | 28 |
| 12. | High speed chases | 65.7 | 27.6 | 65.1 | 25.6 | 12 |
| 13. | Distorted or negative press accounts of police | 65.1 | 24.6 | 55.6 | 23.8 | 29 |
| 14. | Responding to a felony in progress | 64.9 | 24.9 | 68.9 | 17.6 | 8 |
| 15. | Insufficient manpower to handle a job | 64.3 | 23.5 | 63.1 | 19.1 | 14 |
| 16. | Court decisions unduly restricting police | 63.8 | 23.8 | 55.1 | 22.9 | 31.5 |
| 17. | Court leniency with criminals | 63.5 | 24.1 | 59.4 | 21.7 | 21.5 |
| 18. | Excessive or inappropriate discipline | 63.0 | 26.1 | 62.7 | 20.7 | 15 |
| 19. | Put-downs and mistreatment in court | 62.2 | 25.7 | 55.1 | 26.8 | 31.5 |
| 20. | Dealing with family disputes and crisis situations | 61.8 | 23.3 | 62.5 | 19.0 | 16.0 |
| 21. | Demands made by family for more time | 61.6 | 27.7 | 54.0 | 26.2 | 36 |
| 22. | Accident in a patrol car | 61.6 | 26.1 | 64.0 | 19.5 | 13 |
| 23. | Making arrests while alone | 61.2 | 24.7 | 54.8 | 21.0 | 34 |
| 24. | Assignment of incompatible partner | 61.2 | 25.2 | 59.3 | 22.3 | 23 |
| 25. | Political pressure from within the department | 61.0 | 24.5 | 59.0 | 27.1 | 24 |
| 26. | Excessive paperwork | 60.7 | 24.7 | 59.8 | 24.1 | 20 |
| 27. | Poor or inadequate supervision | 60.6 | 26.7 | 60.0 | 22.9 | 19 |
| 28. | Job conflict | 60.3 | 25.2 | 61.3 | 20.4 | 18 |

| | Mail Survey (N=210) | | Pilot Study (N=45) | | |
|---|---|---|---|---|---|
| Items | Mean | SD | Mean | SD | Rank |
| 29. Court appearances on day off or after night shift | 59.7 | 24.2 | 57.9 | 24.3 | 27 |
| 30. Incapacitating physical injury on the job | 58.8 | 29.5 | 65.8 | 27.6 | 11 |
| 31. Competition for advancement | 57.8 | 26.2 | 58.3 | 21.8 | 26 |
| 32. Fellow officers not doing their job | 57.7 | 23.5 | 55.0 | 22.1 | 33 |
| 33. Lack of recognition for good work | 57.2 | 25.8 | 58.6 | 19.7 | 25 |
| 34. Making critical on-the-spot decisions | 57.1 | 26.2 | 61.4 | 21.0 | 17 |
| 35. Difficulty getting along with supervisors | 56.9 | 27.4 | 54.1 | 24.6 | 35 |
| 36. Inadequate or poor quality equipment | 56.8 | 26.5 | 52.8 | 20.2 | 39 |
| 37. Public criticism of police | 55.9 | 24.7 | 48.9 | 21.7 | 47 |
| 38. Ineffectiveness of the correctional system | 55.8 | 26.5 | 52.6 | 23.3 | 40 |
| 39. Experiencing negative attitudes toward police | 55.0 | 24.8 | 49.1 | 22.5 | 46 |
| 40. Working a second job | 53.9 | 25.6 | 55.2 | 20.3 | 30 |
| 41. Public apathy toward police | 53.5 | 25.8 | 53.5 | 19.3 | 37 |
| 42. Racial pressures or conflicts | 53.4 | 27.9 | 53.3 | 22.5 | 38 |
| 43. Personal insult from citizen | 50.7 | 25.2 | 46.7 | 24.0 | 51 |
| 44. Assignment of disagreeable duties | 50.7 | 23.5 | 47.4 | 20.4 | 49 |
| 45. Changes from boring to demanding activities | 50.6 | 26.0 | 49.4 | 24.9 | 45 |
| 46. Disagreeable departmental regulations | 50.5 | 24.1 | 51.4 | 24.4 | 41 |
| 47. Changing from day to night shift (std) | 50.0 | ---- | 50.0 | ---- | 43.5 |
| 48. Lack of participation in decision-making | 49.5 | 26.4 | 46.5 | 23.6 | 52 |
| 49. Political pressure from outside the department | 48.7 | 27.2 | 50.4 | 27.3 | 42 |
| 50. Delivering a death notification | 48.6 | 27.8 | 45.4 | 26.4 | 53 |
| 51. Assignment to new or unfamiliar duties | 46.3 | 23.5 | 47.1 | 21.5 | 50 |
| 52. Assignment of increased responsibility | 45.4 | 25.4 | 50.0 | 21.6 | 43.5 |
| 53. Demands for high moral standards | 43.0 | 26.4 | 40.8 | 25.3 | 58 |
| 54. Exposure to adults in pain | 42.9 | 24.0 | 42.9 | 22.4 | 56 |
| 55. Exposure to death of civilians | 42.4 | 26.0 | 47.5 | 23.1 | 48 |
| 56. Performing nonpolice tasks | 42.0 | 26.0 | 38.4 | 22.5 | 60 |
| 57. Periods of inactivity and boredom | 41.4 | 24.7 | 39.0 | 22.5 | 59 |
| 58. Promotion or commendation | 40.7 | 27.4 | 44.4 | 29.8 | 55 |
| 59. Strained relations with nonpolice friends | 39.6 | 23.7 | 45.2 | 27.3 | 54 |
| 60. Minor physical injury on the job | 38.6 | 24.5 | 41.4 | 24.3 | 57 |

Mr. **Gore**. Thank you very much. We will hold questions until the panel has been completed.

Dr. Gary LeClercq is the medical director with Exxon Chemical Americas in Houston, accompanied by Dr. Gary Krieger.

We are delighted to have you. Please proceed.

[The biographical sketch of Dr. LeClercq follows:]

### GARY KRIEGER, M.D., M.P.H.

Dr. Krieger was born in Valdese, North Carolina. From 1969 through 1978, he received his undergraduate and medical education at the University of North Carolina—Chapel Hill. Post-graduate training in Internal Medicine from 1978 through 1981 was at the Mayo Clinic. After leaving Mayo, Kreiger received in 1982 a Masters Degree in Public Health from the Johns Hopkins School of Public Health & Hygiene. Krieger is board certified in Internal Medicine and will be board eligible in Occupational Medicine.

Beginning in August 1982, Krieger became the Medical Director, Baytown Area, for Exxon Chemical Americas headquartered in Houston. He has done research in hematology, including a year fellowship with the French Red Cross in Paris, cardiology and most recently in chronobiology.

Dr. **LeClercq**. Thank you, Mr. Chairman.

As you mentioned, I am accompanied today by Dr. Gary Krieger, who has played an integral part in our early research at some of our sites in the Houston area.

I would like to thank the committee for inviting us. I also would like to express our appreciation to the committee for bringing together what I feel to be the major characters in this play, who are developing answers and solutions to the problems of shift work.

We have heard from workers and union representatives, we have heard from management, we have heard from university researchers, and we are also going to hear now from occupational physicians.

I think, exactly as you said yesterday, that bringing these groups together is going to take us a long way down the road in developing some very practical answers for our 20 million or so shift workers in the United States.

As we have been hearing over the past few days, recent advances in the study of biologic rhythms have opened a window of opportunity for innovative solutions to the problems of rotational shift work.

This is particularly significant given the fact, as we have heard, that 26 percent of the total American labor force works in some sort of shift work system. In our industry, petrochemicals, this figure may run as high as 35 percent of the labor force. Hence, the potential impact of shift work-related problems poses a unique challenge.

Within the petrochemical industry, there are a variety of shift work schedules involving both 8- and 12-hour schedules. This lack of uniformity mirrors a diverse spectrum of local needs and opinions concerning optimal shift scheduling.

In considering the extent and diversity of these approaches to the design of rotational shifts, one may pose the question: are there measurable differences in health, safety, performance, and social adjustment amongst workers which may be related to shift work and shift schedules?

Stimulated by recent research on the adaptation to biologic rhythms conducted by Dr. Charles Ehret at the Argonne National Laboratory, the Exxon Chemical Americas Medical Department began in the fall of 1982 a series of studies to assess the status of our work force regarding potential consequences of rotational shift work.

To understand our particular needs and concerns regarding shift work one must first recognize that the petrochemical industry reflects several distinct characteristics which differentiate it from other major manufacturing sectors.

First, the petrochemical industry is a capital-intensive rather than a labor-intensive industry; that is to say, modern chemical plants are generally closed process, computer-guided systems rather than open assembly lines. As a result, high levels of continuous worker vigilance at computer control panels are necessary throughout the manufacturing process.

These factors allow small teams of highly trained workers to safely and successfully operate large, multimillion-dollar plants on any given shift. However, as Dr. Ehret and others have previously pointed out regarding control panel operations, there is a need for continuous worker vigilance that is critical from both a safety and a productivity point of view. Thus, any shift system which is utilized should consider both worker health and alertness.

Given these background conditions, we have devised a sequential approach to more clearly define and respond to the health, safety and productivity concerns of continuous rotational shift work.

There are two major steps in our approach:

First, we will generate an extensive chronologic data base on plant performance, charted as a function of three interlocking events: the type of shift schedule in place, the specific manufacturing process, and last, the timing of certain critical events in the manufacturing process.

Based on analysis of this data base, we plan to develop a program geared to promote optimal biologic rhythm adaptation of our workers.

Dr. Gary Krieger of our staff is currently completing a first phase background study at three of our Houston area chemical plants and has generated a novel system of analyzing plant safety and performance records as a function of shift schedule.

We expect this objective data base to give us insight into the multifaceted effect of shift scheduling and allow us to construct a program focused on specific vulnerable periods in a given schedule. In addition, we plan to integrate this effort into our ongoing occupational health programs.

Currently we have presented core scientific information on shift work and biologic rhythms to the top management at all three study sites. With their complete support and encouragement we have begun a comprehensive program with our shift workers.

First, small group conferences are held with all shift workers. Background information is presented and their support and input is elicited. Particular emphasis is placed on safety implications of shift work.

All workers are asked to respond to a confidential questionnaire concerning the potential problem areas of eating, sleeping, and social disruption. Possible solutions are elicited from the workers and openly discussed with them.

A series of training modules on adaptation to shift work will be developed and presented not only to workers, but their spouses. This will be done not only at the test sites, but also at our other chemical plants as appropriate.

We expect these training programs to contain useful information on the timing and content of meals, the type and frequency of work rates, appropriate lighting for control rooms, advice on sleeping habits, and other topics deemed as appropriate.

At the same time, our plant managements are reexamining the scheduling of plant activities toward the goal of obtaining an optimal fit between plant needs and worker capabilities as influenced by shift work.

We are also designing for the control panels computer-oriented, simple, and complex problemsolving tasks which will allow us to one, maintain the alertness of the work force, and two, provide us with objective, measurable data on performance regarding both simple and complex memory tasks.

In the health area, medical screening and monitoring programs are ongoing, with particular emphasis placed on the identification of particular health concerns related to shift work.

Information and updates from our studies will be discussed and presented through normal company channels to workers and management alike, as well as to recognize scientific meetings and publications.

Finally, the entire program will be reevaluated at appropriate intervals.

In conclusion, the need for continuous 24-hour operations is an economic reality in the petrochemical industry. While our program at Exxon Chemical Americas is still in its early stages, we feel that both plant and worker needs can be simultaneously addressed to achieve the common goal of a healthy, satisfied, safe, and productive work force.

Thank you.

[The prepared statement of Dr. LeClercq follows:]

# SHIFTWORK AND THE PETROCHEMICAL INDUSTRY:

## DEFINING CONCERNS - FORMULATING SOLUTIONS

Testimony Before The Investigations And Oversight Subcommittee
Of The
Committee On Science And Technology
U. S. House of Representatives

March 24, 1983

Gary R. LeClercq, M.D.
Medical Director

Gary R. Krieger, M.D.

Exxon Chemical Americas
Houston, Texas

Recent advances in the study of biologic rhythms have opened a window of opportunity for innovative solutions to the problems of rotational shiftwork. This is particularly significant given that 26% of the total American labor force is currently working under some type of shiftwork system. In our industry, petrochemicals, the figure is approximately 35% of the labor force; hence, the potential impact of shiftwork-related problems poses a unique challenge.

Within the petrochemical industry, there is a variety of shiftwork schedules, involving both 8 and 12 hour systems. This lack of uniformity mirrors a diverse spectrum of local needs and opinions concerning the optimal shift schedule. Considering the extent and diversity of these approaches to the design of rotational shifts, one may pose the question, "Are there measurable differences in health, safety, performance and social adjustment among workers which may be related to shiftwork and shift schedules?"

Stimulated by recent research on the adaptation to biologic rhythms conducted by Dr. Charles Ehret at the Argonne National Laboratory, the Exxon Chemical Americas Medical Department began, in the Fall of 1982, a series of studies to assess the status of our workforce regarding the potential consequences of rotational shiftwork.

To understand our particular needs and concerns regarding shiftwork, one must first recognize that the petrochemical industry reflects several distinct characteristics which differentiate it from other major manufacturing sectors:

- First, the petrochemical industry is capital intensive rather than labor intensive.
- That is to say, modern chemical plants are generally closed process, computer-guided systems rather than open assembly lines.
- As a result, high levels of continuous worker vigilance at computer control panels are necessary throughout the manufacturing process.

These factors allow small teams of highly trained workers to safely and successfully operate large multi-million dollar plants on any given shift. However, as Dr. Ehret has pointed out regarding control panel operations, there is a need for continuous worker vigilance that is critical from both a safety and productivity point of view. Thus, any shift system which is utilized should consider both worker alertness and health.

Given these background conditions, we have devised a sequential approach to more clearly define and respond to the health, safety and productivity concerns of continuous rotational shiftwork. There are two major steps in our approach:

- First, we will generate an extensive chronologic database on plant performance, charted as a function of three interlocking events:
  - The type of shift schedule in place
  - The specific manufacturing process
    and last,
  - The timing of certain critical events in the manufacturing process.

- Based on analysis of this database, we plan to develop a program geared to promote optimal biologic rhythm adaptation

Dr. Gary Krieger of our staff is currently completing a first phase background study at three of our Houston area chemical plants, and has generated a novel system of analyzing plant safety and performance records as a function of shift schedule. We expect this objective database to give us insight into the multi-faceted effect of shift scheduling, and allow us to construct a program focused on specific vulnerable periods in a given schedule. In addition, we plan to integrate this program into our ongoing occupational health programs.

Currently we have presented core scientific information on shiftwork and biologic rhythms to the top management at all three study sites. With their complete support and encouragement we have begun a comprehensive program with our shiftworkers:

- First, small group conferences are held with all shift workers. Background information is presented and their support and input is elicited. Particular emphasis is placed on safety implications of shiftwork.
- All workers are asked to respond to a baseline questionnaire concerning shiftwork.
- Potential problem areas of eating, sleeping and social disruption are highlighted, and possible solutions are elicited and discussed.
- A series of training modules on adaptation to shiftwork will be developed.
- Our plant managements are re-examining the scheduling of critical plant activities toward the goal of obtaining an optimal fit between plant needs and worker capabilities.
- Medical screening and surveillance programs are continuing, with particular emphasis placed on identification of potential health concerns related to shiftwork.
- Information and updates from our studies will be discussed and presented through normal company channels to workers and management alike, as well as to recognized scientific meetings and publications.
- The entire program will be re-evaluated at appropriate intervals.

In conclusion, the need for continuous 24 hour operations is an economic reality in the petrochemical industry. While our program at Exxon Chemical Americas is still in its early stages, we feel that both plant and worker needs can be simultaneously addressed to achieve the common goal of a healthy, satisfied, safe and productive workforce.

/mfg
3/14/83

# BIOGRAPHICAL SKETCH

GARY LECLERCQ, M.D. (PRONOUNCED LACLAIR)

DR. LECLERCQ WAS BORN IN SAN FRANCISCO. HE RECEIVED HIS UNDERGRADUATE AND MEDICAL EDUCATION AT STANFORD UNIVERSITY. HE THEN RECEIVED HIS POST GRADUATE TRAINING IN INTERNAL MEDICINE AT KAISER FOUNDATION HOSPITAL IN OAKLAND, CALIFORNIA AND IS BOARD CERTIFIED IN THAT SPECIALTY. HE HAS RECEIVED FURTHER TRAINING IN OCCUPATIONAL MEDICINE FROM THE KETTERING LABORATORY AT THE UNIVERSITY OF CINCINNATI, AND IS BOARD QUALIFIED IN THE SPECIALTY OF PREVENTIVE MEDICINE. FROM 1976 THROUGH 1981, HE SERVED AS MEDICAL DIRECTOR OF NATIONAL STEEL AND SHIPBUILDING COMPANY IN SAN DIEGO, CALIFORNIA, AND IN EARLY 1981 HE JOINED THE MEDICAL STAFF OF EXXON CHEMICAL AMERICAS IN HOUSTON, WHERE HE HAS SERVED AS MEDICAL DIRECTOR SINCE AUGUST OF 1981. HE IS A MEMBER OF THE AMERICAN MEDICAL ASSOCIATION, THE AMERICAN OCCUPATIONAL MEDICAL ASSOCIATION AND THE AMERICAN ACADEMY OF OCCUPATIONAL MEDICINE. HE SERVES ON THE FACULTY OF THE UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AT HOUSTON AS AN ADJUNCT ASSISTANT PROFESSOR OF OCCUPATIONAL MEDICINE AND ENVIRONMENTAL SCIENCES.

Mr. **Gore**. Thank you very much.

The final member of this panel is Dr. Charles F. Ehret, senior scientist in the division of biological and medical research at Argonne National Laboratory, and author and developer of the jet-lag diet.

We are delighted to have you, Dr. Ehret. Please proceed.

[The biological sketch of Dr. Ehret follows:]

March, 1983

## PROFESSIONAL BIOGRAPHY

### Charles Frederick Ehret

Date and Place of Birth: 9 March 1923, New York City

Educational Background:

| | | |
|---|---|---|
| B.S. | College of the City of New York | 1946 |
| M.S. | University of Notre Dame | 1948 |
| Ph.D. | University of Notre Dame | 1951 |

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|---|---|---|
| Bacteriophage Genetics | Cold Spring Harbor | 1949 |
| Physiol., Genetics: Oncology | University of Chicago | 1950 |

Professional Experience:

| | |
|---|---|
| Platoon Leader, Infantry, U.S. 87th Infantry Division (Ardennes, Rhineland) | 1944-1945 |
| Teaching fellow in Zoology, Notre Dame | 1946-1948 |
| Jr. Biologist, Argonne National Laboratory | 1948-1951 |
| Assoc. Biologist, Argonne National Laboratory | 1951-1966 |
| Senior Biologist, Argonne National Laboratory | 1966-present |
| USPHS Fellow, Laboratoire de Biophysique, University of Geneva | 1960-1961 |
| Fridley Lecturer in Chemical Engineering, University of Minnesota | 1963 |
| Visiting Professor in Zoology, Indiana University | 1963 |
| Honors Examiner in Biology, Kenyon, College | 1965 |
| NASA Fellow in Theoretical Biology, Fort Collins, Colorado | 1966 |
| The Honors Board Lectures in Science and Philosophy, State College of Iowa | 1967 |
| Visiting Professor in Oncology, University of Wisconsin | 1971-1972 |
| Group Leader in Biomedical Effects of Energy Transmission and in Neurobehavioral Chronobiology and Toxicology, Argonne National Laboratory | 1978-present |
| Keynote Speaker, 6th Annual University of Nebraska Medical Center Student Research Forum | 1979 |
| George C. Wheeler Distinguished Lectureship, University of North Dakota, Grand Forks | 1980 |
| Distinguished Scientist-Lecturer Series, University of Arkansas for Medical Sciences, Little Rock | 1980 |
| Consultant on Shift-Work in the Power Industry, Commonwealth Edison; Detroit Edison, Ontario Hydro, Philadelphia Electric | 1980;<br>1981-present |
| Visiting Professor of Zoology, University of Texas, Austin | 1981 |
| Consultant in Clinical Chronobiology, Hinsdale Hospital, Hinsdale, IL | 1982 |

Current Research Interests:

Circadian chronobiology: molecular-genetic strategies in the control of the biological clock in higher organism including man; circadian physiological and neurobehavioral effects of high voltage electric fields and of toxic agents.

Charles Frederick Ehret

## Membership in Professional Socieites:

Sigma Xi
American Society of Zoologists
Midwestern Regional Section, Society of Protozoologists (cofounder)
International Society for Chronobiology
International Society for the Study of Time

## National and International Committees:

Committee on Information Problems, Society of Protozoologists (Chairman, 1972-1974)
Committee on Education, Amer. Soc. Zoologists (Member, 1972-1975)
Glossary Committee, International Society for Chronobiology (Member, 1973- )
NCI Committee on Circadian Aspects of Mammary Gland Carcinogenesis in Humans (Member, 1973)
Biotron National Advisory Committee, University of Wisconsin/NSF (Chairman, 1975, 1976, 1977)
Vice-chairman elected) for the 1981 Gordon Research conference in Chronobiology; Chairman of the next, in 1983
Center for Design of Industrial Schedules (Member International Scientific Adivsory Board, 1981- )
Committee on Chronobiological Engineering, International Society for Chronobiology (Chairman, 1981- )
Vice-President, International Society for Chronobiology (1982- )
Consulting Editor, International Journal of Chronobiology (1982- )

## Awards and Honors:

| | |
|---|---|
| Centennial Medal Award in Science, University of Notre Dame | 1965 |
| Argonne Universities Association Distinguished Appointment Award | 1971 |

## Participation in Major Symposia: (By Invitation)

| | |
|---|---|
| Symposium on Information Theory in Biology, Gatlinburg, TN | 1956 |
| AAAS Symposium on Photoperiodism, Gatlingburg, TN | 1957 |
| FASEB Symposium on Biological Clocks, Atlantic City, NJ | 1958 |
| AAAS Symposium on Electron Microscopy, Chicago | 1959 |
| Cold Spring Harbor Symposium on Biological Clocks, Long Island New York | 1960 |
| Finsen Memorial International Congress in Photobiology, Copenhagen | 1960 |
| International Society for the Study of Biological Rhythms, Siena | 1961 |
| Conference on Aging and Levels of Biological Organization, Princeton | 1963 |
| International Congress for Cell Biology, Symposium on Cell Organelles, Providence | 1965 |
| NASA Conference on the Artificial Synthesis of a Living Cell, Fort Collins | 1967 |
| International Society for the Study of Biological Rhythms, Wiesbaden | 1967 |
| FEBS Colloquium on Biochemical Oscillations, Prague | 1968 |
| Symposium on the Physics and Biology of Time, Berkeley | 1968 |
| Friday Harbor Symposium on Biochronometry, Washington | 1969 |
| International Society for Chronobiology, Little Rock | 1971 |
| AUA-ANL Symposium on Photobiology, Argonne | 1972 |
| Smithsonian Interdisciplinary Communications Program on Perspectives in Carcinogenesis, Berkeley Springs, WV | 1972 |

Charles Frederick Ehret

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|---|---|
| AIBS Symposium on Protistan Circadian Rhythms, Amherst | 1973 |
| International Society for Chronobiology, Washington, DC | 1975 |
| International Congress on Rhythmic Functions in Biological Systems, Vienna | 1975 |
| Dahlem Workshop on the Molecular Basis of Circadian Rhythms, Dahlem Konferenzen, Berlin | 1975 |
| LaJolla Conference on Circadian Rhythms, LaJolla, San Diego | 1976 |
| M. D. Anderson Symposium on Fundamental Cancer Research, Houston | 1976 |
| Third International Symposium on the Detection and Prevention of Cancer, New York | 1976 |
| Bay Pines Conference on Biological Rhythms and Aging, St. Petersburg Beach, FL | 1977 |
| International Symposium on Clinical Chronopharmacology, Tallahassee, FL | 1978 |
| Principal Speaker, First Gordon Research Conference in Chronobiology, Plymouth, NH | 1978 |
| 4th Conference, International Society for the Study of Time, Alpbach, Austria | 1979 |
| Faculty member, NATO Advanced Study Institute on Jet-Lag and Shift-Work Hannover, Germany | 1979 |
| Fifth International Symposium on Night- and Shift-Work, Rouen, France | 1980 |
| Toward Chronopharmacology, Satellite Symposium on the 8th International Congress of Pharmacology, Nagasaki, Japan | 1981 |
| Specialist Meeting on Operator Training and Qualification, Committee on the Safety of Nuclear Installations, OECD, Charlotte, NC | 1981 |
| Aylmer Conference on Stress and Law Enforcement, Ontario Police College, Aylmer, Ontario | 1982 |

## Books, Chapters of Books, Review Articles, etc.:

Ducoff, H. S., and C. F. Ehret
Mitogenesis ( The Developmental Biology Conference Series, 1956). Chicago, The University of Chicago Press, pp. 114, 1959.

Ehret, C. F., and E. L. Powers
The Cell Surface of Paramecium
In Intern. Review of Cytology, New York, Academic Press
Vol. 8, pp. 97-113, 1959.

Ehret, C. F., and J. J. Wille
The Photobiology of Circadian Rhythms in Protozoa and Other Eukaryotic Microorganisms. In Photobiology of Microorganisms
Ed. Per Halldal, John Wiley, pp. 369-416, 1970.

Ward, R. R. "The Living Clocks" Chapter 18, written by Ward, is entitled "Ehret: Clocks at the Base of Life." Alfred A. Knopf, NY, pp. 324-337, 1971.

Ehret, C. F., and E. W. McArdle
The Structure of Paramecium as Viewed from Its Constituent Levels of Organization
In the Biology of Paramecium. Ed. W. Van Wagtendonk, Elsevier Press, pp. 263-338, 1975.

Charles Frederick Ehret

Ehret, C. F.
The Sense of Time: Evidence for its Molecular Basis in the Eukaryotic Gene Action System. In Adv. in Biol. and Medical Physics, Academic Press, New York, Vol. 15, pp. 47-77, 1974.

Ehret, C. F., J. C. Meinert, K. R. Groh, K. W. Dobra, and G. A. Antipa
Circadian Regulation: Growth Kinetics of the Infradian Cell. In Growth Kinetics and Biochemical Regulation for Normal and Malignant Cells, B. Drewinko and R. M. Humphrey, eds., Williams and Wilkins Co., Baltimore, 1977.

Ehret, C. F.
On Circadian Cybernetics, and the Innate and Genetic Nature of Circadian Rhythms. In Chronobiology: Principles and Applications to Shifts in Schedules. Eds. L. E. Scheving and F. Halberg, Sijthoff and Noordhoff, Alphen aan den Rijn, Netherlands, pp. 393-402 (1980).

Ehret, C. F.
The Chronon Theory of Circadian Rhythm Control. In Chronobiology: Principles and Applications to Shifts in Schedules. Eds. L. E. Scheving and F. Halberg, Sijthoff and Noordhoff, Alphen aan den Rijn, Netherlands, pp. 229-238 (1980).

Ehret, C. F., K. R. Groh and J. C. Meinert
Considerations of Diet in Alleviating Jet Lag. In Chronobiology: Principles and Applications to Shifts in Schedules. Eds. L. E. Scheving and F. Halberg, Sijthoff and Noordhoff, Alphen aan den Rijn, Netherlands, pp. 109-125 (1980).

Ehret, C. F.
New Approaches to Chronohygiene for the Shift-Worker in the Nuclear Power Industry. In Night and Shift-Work: Biological and Social Aspects, Eds. A. Reinberg, N. Vieux and P. Andlauer, Pergamon Press (1981).

Ehret, C. F., J. C. Meinert and K. R. Groh
The Chronopharmacology of L-DOPA: Implications for Orthochronal Therapy in the Prevention of Circadian Dyschronism. In Chronopharmacology and Chronotherapeutics, Eds. C. A. Walker, K. F. A. Soliman and C. M. Winget, Florida A&M University, Tallahassee, pp. 47-65 (1981).

Ehret, C. F. and L. W. Scanlon
Overcoming Jet Lag. Berkley Publishing, New York, 1983.

Dr. EHRET. Thank you very much, Mr. Chairman.

As you have heard over the past 2 days, shift work fatigue and transmeridial fatigue, or jet lag, share a lot of common properties. One of my favorite sources, the celebrated columnist Erma Bombeck, says it is a lot like standing up on a crowded subway train all the way from Bulgaria to New York.

In sifting through and collating the testimony presented to this committee, I want to see if we can arrive at a better definition than Mrs. Bombeck's for you to carry home with and for us to use in defining future perspectives sensibly.

First, let us recall into sharp focus several facts about the shift rotation schedules, or ROTAS, in use in the world today, especially as exemplified by the electric power industry.

Many of these ROTAS are manifestly harmful to the health of their practitioners and hazardous to the successful outcome of the task for which they were designed. These faults in design include most infamously the ROTA in use on Wednesday, the 28th of March, 1979 at Unit II of the Three Mile Island nuclear power station at the time of the well-known and costly accident. I think we at Argonne were the first to point that out.

Attributed principally to human error, it resulted in the most serious blow ever suffered by the nuclear powered industry. Although this particular ROTA, slow rotation by phase advance, is universally condemned by every expert on shift work, it continues to be used by key workers in over half of the power industry in the world today.

As a consequence, it has taken and continues to take an immeasurable toll of ransom and mischief in the form of losses in power, in revenue, in property and time. Bad ROTAS such as this also take their tolls in human lives, not only as measured by workers whose lives are lost in catastrophic accidents—and I think the references here you should look to, especially in the maritime industry—but also the toll is taken by these workers because they are dehumanized by the very design and circumstance of work itself.

This form of dehumanization—that is to say, a decrement in physiological, psychological and spiritual values and in the whole quality of life—has been decried in John Paul II's 1981 encyclical on human work. It is clearly a spinoff of bad ROTAS, as described extensively in the literature and vividly in interviews with and in letters from shift workers.

Shift work fatigue is not fatigue of the garden variety. When you come in from playing a game of tennis, that kind of fatigue is a fatigue of feeling good. You are coming in from climbing a mountain or swimming or working in the garden, and you feel great, though tired. Shift work fatigue is a transient condition of mental and physiological dysfunction.

The second point I want to make is that shift work has been around for a long time. As I point out in the written testimony, even horses in imperial Rome suffered from it.

Something new has happened, something new is on the scene now. You have been listening to it for the past day and a half. Concurrent with the appearance of recent reviews of work—in the older literature, mostly descriptive in character—a whole new literature on carefully calculated intervention on the causes, on the cures, on the prevention, on the amelioration of shift work fatigue has just appeared.

These newer references point up the biological and the neurological bases for the problem. Then from that firm foundation they go on to propose solutions. We heard about them yesterday from Dr. Czeisler and Dr. Moore-Ede.

The solutions offered to date have focused in a reductions approach to two sides to the coin of the problem of shift work.

The two sides to the coin of the problem are on the one hand, the problem of the ROTAS; that is to say, the shift rotation schedule. In the airlines industry it is the schedule that you take when you decide to go to Hong Kong. If you arrive at 2 in the morning, that is a bad idea.

The other side of the coin is the coin of what we call chronohygiene. It comes from the understanding of the signals that can be used to reset the clock. We all know that we can reset the wristwatch on our wrist very readily. We take thumb and forefinger and in something like a millisecond we can reset that clock.

These billions of cells in the central nervous system and in the other organs of the body, each of these is a clock. They go into cohorts. There are at least two cohorts that we heard about yesterday. But each is a clock, each requires resetting, and how do you do it, where is the resetting mechanism?

Mr. **Gore**. Let me interrupt. When you say cohorts, you mean the two large body clock systems that have been identified: one, the sleep-wakefulness clock, and the other the body temperature alertness clock?

Dr. **Ehret**. I am thinking especially of the suprachiasmatic nucleus of the hypothalamus as representing a large number of cells.

Mr. **Gore**. You took the words right out of my mouth, Doctor. [Laughter.]

Dr. **Ehret**. At any rate, what we know is that we can reset these clocks with agents that are called zeitgebers. It is a word you ought to learn, from the German word zeitgeber, time giver. There is a short laundry list to think of: Light and the light-dark cycle. We heard of that from Dr. Wehr yesterday.

Food: Programed feeding; the quality of the food, whether it is a high protein meal or a high carbohydrate meal. High protein meals stimulate the catecholamine pathway, the adrenalin pathway, which is characteristically on early in the morning, wakes you up in the morning, gets you going, along with the hormones of the adrenal cortex turning on.

A high carbohydrate meal, on the other hand, stimulates the pathway of indoleamines, on the way to the build of serotonin in the brain, which when it reaches a certain level is usually coincidental with sleep.

So, if you get up in the morning and have Sugar Krispies and sugar water for breakfast, in effect it tells you to go back to bed again; something more like a steak and eggs for the breakfast routine.

We have a short list of drugs here. First of all, the methyl xanthines: Caffeine, theophylline, theobromine, coffee, tea, cocoa, chocolate, cola beverages. Each of these is a zeitgeber. Each is a very effective clock resetter.

Still further down the list, the bulk of the American pharmaceutical industry: Tranquilizers, antihypertensives, alpha methylpherateracine, El Dopa, even LSD, each of these is a very effective drug in influencing the circadian clock pathway.

Still further down the list, oxygen, probably best in use with exercise.

Finally, what we heard about yesterday briefly, social cues, interpersonal activity. In considering these two sides of the coin of shift work, we see two definite areas in which intervention can happen, where we can do some work.

Incidentally, most recently we have found in my laboratory that 60 hertz electric fields are also circadian zeitgebers, but they have to be used at extraordinarily high field strengths.

So, in the electric power industry, a man who is working in the field under high tension lines would in fact get field strengths high enough to reset his clock. If he is already a shift worker, these together in synergism could exacerbate the problem. Of course, we know that the death rate among these people is very, very high. In Ontario Hydro, it is in excess of a dozen a year.

Another point to realize, as we heard the word "stress" used in a very general sense, every one of these zeitgebers is a stresser, except that at one time of day, when taken at the right time, it is good for you. So, there is a time of day when you would say it was good and a time of day when you would say it was bad.

It is lovely to be on a Florida beach in the wintertime, basking in the sunshine, but you don't want it in your bedroom at 3 in the morning. That goes right through the whole list, including social cues.

For the future, action can be taken in three key areas: First, facilitated dissemination of information; second, chronobiological engineering; and third, basic research.

In the first area, sound recommendations are possible already for immediate action. For example, we already know enough about circadian chronohygiene to instruct workers on how to maintain the integrity of their body clocks on fixed shifts and on how to reset their rhythms during shift rotation more rapidly.

Furthermore, on the subject of ROTAS, there is universal agreement that certain rotation schedules are to be avoided, such as those that rotate by phase advance. All shift workers, along with their immediate families, would benefit from training programs—like the training modules that I am happy to learn have been adopted by Exxon—on the nature of shift work, and these training programs are similar to the training programs that are used in the nuclear power industry.

Every shift worker should be required to learn what is shift work. It is the way we teach sex hygiene to our teenage children in the high schools now. These courses should include at least its connection to the circadian biological clocks of the body, the amelioration of adverse effects through the application of circadian chronohygiene, and the scientific design and use of shift work ROTAS.

Yesterday the question came up about where do these ROTAS come from. The chairman asked that question. In our early survey of the nuclear power industry we found—and in fact in the whole electric power industry in the world—tradition ruled. They always have done it this way. They did it this way in the Buffalo Steel Works in 1916. It is the DuPont method. Or sometimes by virtue of a kangaroo court. Some fellow, John Doe, decided this is the way it really works, fellows, and they voted on that. Never scientifically in our survey of the literature.

Regarding these measures of teaching, several leading North American institutions and businesses are already actively engaged in the implementation of such measures as these through their human factors, medical and personnel training resources.

Amongst these include Ontario Hydro, a leading power company in Canada; Commonwealth Edison in Chicago; the Ontario Police College, the leading police college on the continent; Exxon Houston, our own breeder reactor at Argonne West—in May 1981 we shifted schedules there—and in a smaller area mainly having to do with the transportation of executives transmeridially, the Control Data Corp. in Minneapolis and the Bechtel Corp.

However, even though we have come such a long way in our understandings of the problem as to recommend immediate and effective measures, we still have a long way to go. That is the second area in which we recommend that chronobiological engineering be introduced.

This has to do with amelioration, mitigation, plus measurement. It is intervention with testing. It is not enough to give the worker a method. It is like giving him a rabbit's foot, unless you in fact measure to see that things are working better or worse as a consequence of the measure.

There are, for example, already mixed reports on the blessings or curses to be associated with rapid rotation, widely used in the French petroleum industry, it is used in Scotland, in England, in the United Kingdom, and it is even used at Eastman-Kodak, Rochester, a very unwise decision because it may in fact introduce something that looked very much like manic depression in the long wave form that one sees from animal studies.

So, this paradox, that there is a certain preference for rapid rotation and the fact that it looks bad from other circumstances, has yet to be resolved by further investigations in the field.

We have to look into the screening and testing of individuals on suitability for them to do shift work; we have to look into the design of ambulatory instrumentation, such as the wrist actigraph that Dr. Wehr was wearing yesterday; further measurement also of temperature, without rectal temperature; vigilance and cognitive function. We need easy measures of all of these, something you can wear on your belt and have it click away for a week or two, collecting data.

How many industrial accidents, how many air and bus traffic catastrophies, how many rammings, groundings and collisions of ships at sea, most of which are already attributable to human error? That is in reference 8. At least 75 percent and probably 85 percent of these accidents from that study are on account of human error.

How many of these are attributable to human error arising from faulty shift ROTAS and from bad circadian chronohygiene? How soon can we test new ROTAS of optimal design that follow the natural pre-run rhythm of the 25-hour day?

Finally, the third category, basic research. What more can we do about extending the short list of synchronizers or multiple zeitgebers that I mentioned a while ago? Will we some day see a pill to reset the clock? I doubt it very much. It will be more like a lifestyle of synchronizing all the multiple zeitgebers together.

But we do know that some of the drugs, some of the cyclotropic drugs especially, are extraordinarily effective in this area. There is a right time to take them and there is a wrong time to take them from the point of view of resetting the biological clock.

Are there other deleterious sequelae to shift work beyond even the well-documented neuroses and gastritis that we have not yet measured? For example, is shift work carcinogenic? There is theoretical reason to believe that it is to some slight degree. Is it life-shortening? There is experimental evidence to show that it is, even to a slight degree.

These basic questions have been asked, but they remain yet to be answered in the years ahead. The sooner we get on with the work, the more productive the workplace will be for industry and the safer the workplace will be for hundreds of thousands of our fellow Americans, elite inhabitants of the time ghettos of the Nation—our dedicated shift workers.

Through proper chronobiological engineering we can achieve a WIN-WIN scenario, like the one that we hear the Exxon group going after, in the workplaces of the Nation, good for the worker, good for production, a scenario that we cannot afford not to develop to the fullest.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Ehret follows:]

# Future Perspectives for the Application of Chronobiological Knowledge in Occupational Work Scheduling

Charles F. Ehret*

Invited Testimony for the Investigations and Oversight Subcommittee
of the Commitee on Science and Technology
U.S. House of Representatives, Washington, DC
24 March 1983

In a landmark paper that included the results of the largest study ever made of the role of shift-work in Japanese industry, the Japan Association of Industrial Health recommended not only that the very issue of introducing shift work should be made subject to legal regulation, but also that "...in particular, the introduction of shift work for economic reasons related to accelerated depreciation of costly machinery or managerial efficiency must be prohibited."[1]

Why, then, should so august a body make so apparently harsh and severe a judgement in such a highly industrialized society as contemporary Japan? Does this recommendation apply to our own society as well? Is shift work so bad for one's health as to be decreed, in effect, illegal? Are any professions exempt? What is the basic nature of the problem, and in its resolution, what steps can be taken to ameliorate its deleterious effects? These are some of the questions that have been touched upon in testimony presented during the past day and a half.

Shift work is as old as recorded history. Practitioners of this oldest profession included camp guards and, later, shepherds, who kept their watch at night around the early encampments of nomadic and post-nomadic man. As civilization progressed, more practitioners joined the ranks of security and law enforcement agents, and in Nero's time truck deliveries were prohibited in the streets of Rome during daylight hours, resulting in a nightly traffic of horse drawn vehicles so noisy that many patricians, unable to sleep through the nightly din, moved out of town to the relative quiet of the countryside. The poet Ovid had earlier written "lente, lente currite noctis equi"--slowly, slowly run the horses of the night. So, in those days, even the horses suffered from "shift work fatigue," a malaise in which etiology and symptoms bear a striking resemblance to "jet lag."

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One of the earliest recorded decrees against such nocturnal activity was made by William the Conqueror, at Rouen, in 1061, even before the conquest of Britain by the Normans. His edict of the "couvre feu" required the nightly extinguishing of fires and "lights-out" at nine p.m., and is observed to this day, in one or another form in communities around the world, as the curfew.

Thus, until the onset of the industrial revolution, the number of shift workers in society remained small and was confined largely to the security and law enforcement professions and to a small range of public service activities, including transportation, baking and health care. Since the turn of the century, in response to an accelerating demand to keep the foundries and the factories going "round-the-clock," the ranks of shift workers have proliferated unceasingly. Today, with even computer programmers and operators swelling these ranks, approximately 15-25% of the work force of our industrial cities is comprised of shift workers.

What is shift work? In its broadest and simplest definition, it is any work that requires the worker's presence during what are normally regarded as off-hours; since man is normally a day-active creature, this means any work that includes a considerable share of nighttime activity.

Today, literally thousands of forms of shift rotation schedules--or ROTAS, as they are known--are practiced in a wide range of professions.

Despite their wide variety, in a severely reductionist classification, we may reduce their diverse patterns to six archetypal categories:

1. Slow rotation by phase advance
2. Slow rotation by phase delay
3. Rapid rotation (1-1-1)
4. Rapid rotation (2-2-2)
5. Dedicated shifts
6. Optimized ROTAS

By slow rotation we mean that at least a week is spent on a shift before rotation to the next one. By phase advance, we mean that the direction of rotation is from the night (*n*) to the afternoon (*a*) to the morning (*m*) shift. By phase delay we mean rotation in the direction *m*-*a*-*n*, in which, as a worker rotates from one shift to the next, he gains an extra 8 hours of sleep. Rapid rotation refers to any ROTAS that cycle through several shifts in less than a week: 1-1-1 for example, means Monday *m*-shift, Tuesday *a*-shift and Wednesday *n*-shift; this rapid cycle is then followed by 1 or 2 days off, and a return to the cycle; 2-2-2 Monday and Tuesday = *m*-shift, Wednesday and Thursday = *a*-shift, etc.; these are examples of the patterns of the celebrated Metropolitan and Continental ROTAS widely used in the French petroleum industry and in the steel industries of Britain and western Europe. Dedicated shifts are those in which the worker spends all of his days on either the *a* shift or the *n* shift without rotation. Optimized ROTAS are those deliberately designed to match the normal daily rhythms or circadian cycles of human physiology.

Many of these ROTAS are manifestly harmful to the health of their practitioners and hazardous to the successful outcome of the tasks for which they were designed.[2-5] These faults in design include most infamously the ROTA in use on Wednesday, March 28, 1979, at Unit 2 of the Three Mile Island Nuclear Power Station at the time of the well known and costly accident, attributed principally to human error, which resulted in the most serious blow ever suffered by the Nuclear Power Industry.[6] Although this particular ROTA, "slow rotation by phase advance," is universally condemned by every expert on Shift Work, it continues to be used by key workers in over half of the power industry in the world today. As a consequence, it has taken, and continues to take, an immeasurable toll of ransom and mischief in the form of losses in power, revenue, property and time. Bad ROTAS such as this nearly ubiquitous "slow rotation by phase advance" also take their tolls in human lives, not only as measured by workers whose lives are lost in catastrophic accidents,[7,8] but also by those workers "dehumanized" by the very design and circumstance of the work itself. That this form of "dehumanization"--that is to say, a decrement in physiological, psychological and spiritual values such as decried in John Paul II's 1981 encyclical "On Human Work"--actually occurs as a spin-off of bad ROTAS, is described extensively in the literature, and vividly in interviews with, and in letters from, shift workers. Shift-work fatigue is *not* fatigue of the garden variety, such as one experiences after a game of tennis or golf. Shift-work fatigue is a transient condition of mental and physiological dysfunction.

Concurrent with the appearance of recent reviews of work from the older literature, mostly descriptive in character (cited above, Refs 1-5), a new literature on carefully calculated intervention--on the causes and cures, on the prevention and amelioration--of shift-work fatigue has appeared.[6,9-12]

These newer references point up the biological and neurochemical bases for the problem,[6,9,10] and then from that firm foundation, go on to propose solutions. The solutions offered to date have focused, in a reductionist approach, upon two sides to the problem of shift work: the one being the application of Circadian Chronohygiene measures[6,9] to ameliorate the deleterious effects of even the best of ROTAS, and the other being the scientific design and selection of ROTAS.[11,12] In the course of these considerations, the need to reduce the number of workers employed as shift workers to an absolute minimum, has become clear, and the need to include in that number ultimately only those workers essential for society's needs (unless better solutions are found and practiced) has become evident. Included in that small but select workforce constituting an elite vanguard of worthy public servants are workers in the Law Enforcement and Security Professions, in the Power, Communications and Transportation Industries, and in the Health Care Professions.

For the future, further studies are needed in several key areas; but even before these begin, sound recommendations are possible for immediate action in several areas. For example, we already known enough about circadian chronohygiene to instruct workers in how to maintain the integrity of their "body clocks" on fixed shifts, and on how to reset their rhythms during shift rotation.[13] Furthermore, on the subject of ROTAS, there is universal agreement that certain rotation schedules are to be avoided, such as those that rotate by phase advance. All shift workers along with their immediate families would benefit from training programs on the nature of shift work: 1) its connection to the circadian biological clocks of the body, 2) the amelioration of adverse effects through the application of circadian chronohygiene, and 3) the scientific design and use of shift work ROTAS.

Several leading North American institutions and businesses are already actively engaged in the implementation of such measures as these, though their human factors, medical and personnel training resources.[14]

However, even though we have come such a long way in our understandings of the problem as to recommend immediate and effective measures, we still have a long way to go. There are, for example, mixed reports on the blessings[5] or curses[5,12] to be associated with Rapid Rotation ("1-1-1", or "2-2-2") ROTAS, and this paradox has to be resolved by further investigations in the field, and in the laboratory. How many industrial accidents, how many air and bus-traffic catastrophes, how many rammings, groundings and collisions of ships at sea (most of which are already attributable to human error)[8] are attributable to human error arising from faulty shift-work ROTAS and from bad circadian chronohygiene? How soon can we test new ROTAS of optimal design, that follow the natural free run rhythm of a 25 hour "day"? What more can we do about extending the short list of synchronizers (multiple zeitgebers)[6,9,14,15] in order to reset circadian rhythms even more effectively than now? Are there other deleterious sequelae to shift work (even beyond the well documented neuroses and gastritis) that we have not yet measured--for example, is shift work carcinogenic or life shortening, even to a slight degree? These basic questions have been asked, but remain yet to be answered in the years ahead. The sooner we get on with the work, the more productive the work place will be for industry, and the safer the work place will be for hundreds of thousands of our fellow Americans, elite inhabitants of the "time ghettos" of the nation--our dedicated shift workers. Through proper chronobiological engineering we *can* achieve a "WIN-WIN" scenario in the work places of the nation, good for the worker, good for production,--a scenario that we cannot afford not to develop to the fullest.

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13. Tens of thousands of transmeridional travelers, representing all of the leading professions and principal branches of the government (including the Army, the Navy and the OMB) are already successfully using similar methods in the amelioration of jet lag, a condition essentially similar to shift-work fatigue.
14. e.g., attachment "Aylmer Conference on Stress and Law Enforcement," Ontario Police College, Aylmer, Ontario, 2-3 November 1982.
15. "Multiple Zeitgebers" (or circadian-rhythm synchronizers) include Light, Food, Quality of Food (high in protein or high in carbohydrates), Drugs (caffeine, theophylline, theobromine in coffee, tea, cocoa and cola beverages), Exercise, Oxygen (deep breathing, aerobic dancing), and Social Cues (interpersonal interactions, business work, etc.).

Invited paper, "Aylmer Conference on Stress and Law Enforcement"
Ontario Police College, Aylmer, Ontario,
2-3 November 1982.

# A Chronobiological Approach to Shift-Work: Circadian Chronohygiene and Advanced ROTAS for the Law Enforcement and Security Professions

Charles F. Ehret*

Definition of Shift Work

History of Shift Work

- From the Romans
- To the Middle Ages (and the couvre-feu)
- To the present

Scope of Present Studies

- Shift Rotation Schedules (ROTAS) and Circadian Chronohygiene (see below)

Is Shift Work Necessary?

- When?
- In what industries?
- By whom?

## NATURE OF THE PROBLEM

Circadian Rhythms and the Human Body Clock

- Social and psychological problems
- Physical, mental and spiritual problems
- Performance, errors, accidents and catastrophes

## CIRCADIAN REGULATORY BIOLOGY & HUMAN RHYTHMS

The Circadian Biological Clock

- Its ubiquitous nature - the circadian chronotype
- Zeitgebers, chronobiotics, phase response curves
- Biochemistry & neurochemistry
- Dyschronogens, Dyschronism
- Sleep disorders, cognitive functions, psychomotor performance, neuroses & psychoses
- Amelioration & prevention of dyschronism

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TWO SIDES TO THE COIN OF SHIFTWORK: CHRONOHYGIENE/ROTAS

CHRONOHYGIENE

- Light & dark
- Food (quality of food, high protein, high carbohydrate)
- Drugs (methyl xanthines, tranquilizers, antihypertensives)
- Oxygen (exercise, aerobic dancing)
- Social cues

ROTAS

- Shift work rotation schedules
- Dedicated shifts
- Slow rotation - phase advance
- Slow rotation - phase delay
- Rapid Rotation (1-1-1) (2-2-2) (metropolitan and continental ROTAS)
- ROTAS of advanced design (ROADS)

IMPLEMENTATION

Role of Administrative Personnel

Role of Technical Personnel

Measurement & Reporting

Iterative and Cooperative Interactions

Teaching

*Reprinted from*

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Night and Shift Work
Biological and Social Aspects

Edited by
Reinberg et al.
Pergamon Press Oxford and New York 1981

# NEW APPROACHES TO CHRONO-HYGIENE FOR THE SHIFT WORKER IN THE NUCLEAR POWER INDUSTRY

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## ABSTRACT

Equipment failure arising from human error during operations can have catastrophic consequences in the nuclear power industry. The incident at the Three Mile Island (TMI) nuclear power plant in Pennsylvania has been identified as one that was exacerbated by operator error. The time course of this accident strongly suggests that poor circadian chronohygiene was a contributing factor, and that the operators on duty were at less than optimal phase in their individual daily performance cycle. Analysis of shift work practices in the U.S. power industry reveals a pattern of slow rotation with weekly shifts, not unlike that at TMI, often associated with chronobiologically less desirable phase advances rather than phase delays to achieve the shifts. Present evidence shows that the usual schedule causes measurable deficits in human performance, including decreases in visual acuity, elementary cognitive function, and general vigilance. The options for mitigation include, first, rapid rotation, second, dedicated shifts, and third, slow rotation *implemented by circadian chronohygiene* to accelerate phase shifts. We reject the first option, especially for plant operators, and for other individuals *with critical decisions to make,* because it discourages phase shifts, and sometimes encourages dyschronism, both contributing to performance deficits in the very early morning hours. We reject the second option because of the scarcity of eligible cadre, and the negative influence of shift preference on crew morale. We propose the third as a viable alternative to encourage responsible crew performance around the clock. In our design we exploit methods that have proven to be effective in accelerating the shifting of the activity phase of circadian rhythms in humans. These methods include the programmed timing of meals, drugs, exercise, sleep and social cues, as multiple cues (zeitgebers) administered orthochronally, that is, at the most effective time.

## KEYWORDS

Accelerated phase shifts, circadian chronohygiene, multiple zeitgebers, nuclear power industry, orthochronal, shift preference, slow rotation, Three Mile Island.

## INTRODUCTION

One of the serious challenges to the continued use of nuclear power occurred last year when "a combination of design deficiency, mechanical failure and human error contributed to the ill-controlled accident that was touched off at about 4 a.m. on Wednesday, March 28, at Unit 2 of the Three Mile Island (TMI) nuclear power station" (Payne, Blake and FitzGerald, 1979). The repercussions were heard round the world as a political and economic calamity. A leading proponent of nuclear power expressed concern that "human error could result if low pay results in inadequately trained or overworked operators at nuclear plants" (Teller, 1979). A more neutral editorial source (Chicago Tribune, May 14, 1979) declared as fact that "nuclear power is terribly unforgiving of human error." The seriousness of the TMI accident, developing as it did from human error, was in a very real sense avoidable. Analysis of the time course of the accident[1] and of the testimony of the operators strongly suggests that poor circadian chronohygiene was a major contributing factor to error proneness. Not unlike the pilot and copilot in the cockpit of a transoceanic jet, the nuclear power plant operator in his control room is confronted by a complex array of instruments and instrument panels (Fig. 1) and "a heavy continuous call on vigilance in an otherwise monotonous environment (that) may give rise to a higher nocturnal accident rate by way of interaction of fatigue and the circadian variation of arousal" (Klein and Wegmann, 1979a). The crew at TMI had just passed the middle of its night shift (2300-0700 h) when the accident occurred, and the crew members had been on a cycle of slow rotation (1 week) with rotation rounds repeating every sixth week. It is hoped that the measures in circadian bioengineering recommended here may be of some help in preventing future accidents in energy

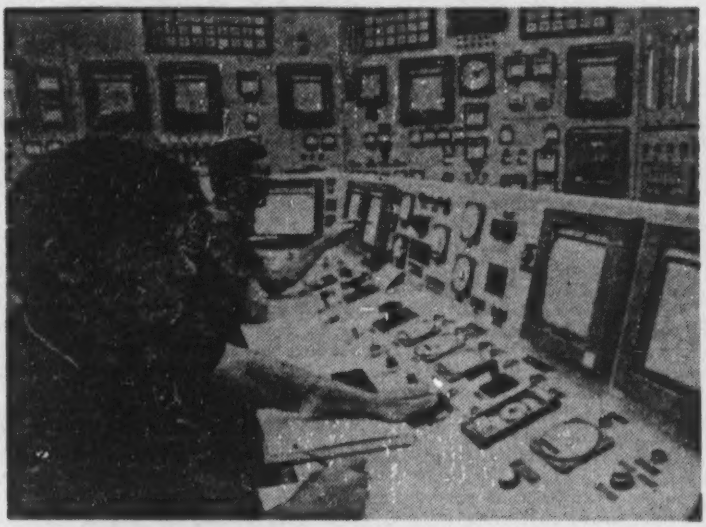

Fig. 1. Nuclear power plant operators in the control room of the experimental fast breeder reactor EBR-II of the U.S. Department of Energy's Argonne National Laboratory-West, near Idaho Falls, Idaho.

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[1] Our principal sources included reports from the Annotated Sequence of Events, TMI Staff Interviews, and Shift Work Schedules at TMI, in the form of General Public Utilities Releases to R. V. Laney and C. F. Ehret during April and May 1979.

systems such as coal mines and power plants that require heavily staffed round-the-clock operations and in which human error arising from circadian chronotypic fatigue can have catastrophic consequences.

## Shift Work Practices in the Power Industry

Is the work pattern of slow rotation (1 week) commonplace or rare in the power industry? At two recent meetings on jet-lag and shift work[2,3] no one seemed to know the answer to this question, although guesses among the European shift work attendees were that much of Western Europe was either moving to or already on rapid rotation (1 or 2 days). On the other hand, the American nuclear and fossil-power engineering attendees unanimously guessed that slow rotation (~ 1 week) was the rule. A survey appeared in order, and its results are given in part below.

A questionnaire was mailed to 120 companies and power authorities in North America, Western Europe, Africa and Asia. Summarized in Table 1 are the results received from 92 of these plants and power stations, including 51 functioning nuclear, and

TABLE 1 Argonne Shift Work Scheduling Survey

| | North America | | Western Europe, Africa and Asia | |
|---|---|---|---|---|
| | Nuclear | Non-Nuclear | Nuclear | Non-Nuclear |
| Satisfied with Schedule Now in Use | 9 | 7 | 14 | 5 |
| Need for Minor Improvements | 10 | 9 | 7 | 1 |
| Need for Major Improvements | 6[a] | 11[a] | 0 | 1[b] |
| No Opinion Expressed | 3 | 7 | 2 | 0 |
| Shifts Rotate by Phase Advance($\Delta\phi^+$) | 15 | 22 | 4 | 4 |
| Shifts Rotate by Phase Delay($\Delta\phi^-$) | 6[c] | 7[c] | 12[c] | - |
| Shifts Rotate by Both $\Delta\phi^+$ and $\Delta\phi^-$ | 4 | 3 | - | 1 |
| Fixed Shifts (in some operations) | (2) | (3) | 0 | 0 |
| 12 h Shifts, Rapid Rotation (2-3 d) | 0 | 1 | 0 | 0 |
| 8 h Shifts, Rapid Rotation (2-4 d) | 0 | 0 | 8 | 4 |
| 8 h Shifts, Slow Rotation (5-7 d) | 28 | 33 | 15 | 3 |

[a] Of these 17 plants, 11 rotated by phase advance, and 3 by both phase advance and phase delay.

[b] This is one of the 4 plants in this group rotating by phase advance; some respondents failed to give information regarding phase change of the rotas (-).

[c] Of these 25 plants, 19 expressed "entirely satisfied", and of the remaining 6, 4 expressed only the need for more time for training purposes.

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[2] NATO Advanced Study Institute on Principles and Application of Chronobiology to Shifts in Schedules with Emphasis on Man, Hannover, W. Germany, July 1979.

[3] ONR/NIOSH Symposium on Variation in Work-Sleep Schedules: Effects on Health and Performance, San Diego, September 1979.

41 non-nuclear, including fossil fuel and hydroelectric generators. The prevailing rotation pattern in North America was "7-15-23" (see Östberg, 1973) ± 1 h; with no exceptions in 56 cases. The rotation pattern in Western Europe had a broader distribution, from "6-14-22" to "8-16-23", and Japan and Korea fell into the "8-16-23" category. In all but one of the slow rotation schedules, the intervals between rotation varied around 5-7 d; the exceptional case used a 10 d interval. The remarkable similarity among schedules, as if most were derived from one master plan, is interesting in view of the fact that some have been in effect in the same plant for over 40 years, and 20 of those included in the survey of non-nuclear plants for at least 30 years. A common complaint associated especially with the nuclear plants is that "more crews and more time are needed for training." The emergence of a correlation between satisfaction with schedules that permit rotations by phase delay, and dissatisfaction with schedules that rotate by phase advance is indicated in the Table. It is clear from the above that slow rotation (∿ 1 week) is the prevailing mode of shift work. Some plants are seriously considering the move from an 8 h to a 12 h day. It is also clear that rotation by means of phase advance (the worker goes to his job 8 h earlier with each rotation) is much more common than by means of phase delay. However the latter scheme (phase delay) appears to accomplish phase shifts more readily without degradation of performance of several task variables (Klein and Wegmann, 1979b; Halberg, Reinberg and Reinberg, 1977).

## Circadian Chronohygiene for the Shift Worker

Available evidence shows that the kind of slow shift rotation (1 week) most commonly used in the nuclear power industry, as well as in the fossil fuel and hydroelectric power industries, results in variable degrees of circadian dyschronism and significant deficits in performance of a variety of tasks including tests for visual acuity and elementary cognitive function (Colquhoun, 1976; Rutenfranz, 1978; Winget, Hughes and LaDou, 1978; Folkard, 1980). *A priori* the options for mitigation include first, rapid rotation (1 or 2 days), second, dedicated shifts, and third, slow rotation implemented by circadian chronohygiene to accelerate phase shifts. The first method tends to maintain the worker's circadian rhythms on home time irrespective of his shift, and to favor his social and home life; it may be most desirable in a large number of relatively noncritical or low hazard enterprises. However, for plant operators, and for other individuals with critical decisions to make, we find this method unacceptable because it discourages phase shifts and sometimes encourages dyschronism. Both results contribute to performance deficits in the very early morning hours. The second method may be ideal for small power companies in which a sufficient number of personnel permanently dedicated to a single shift without rotation may be available; in larger plants dedicated shifts are difficult to man because of a scarcity of eligible cadre. Further, dedicated shifts exert a negative influence of shift preference on crew morale. The most viable of the three alternatives proposed to encourage responsible crew performance around the clock is a modified slow rotation plan (> 1 w < 5 w) that is supplemented by circadian chronohygiene phase shifting techniques at the time of rotation. The phase shifting techniques center upon the simultaneous orthochronal application of multiple zeitgebers including: (1) programmed feeding and the use of food as a zeitgeber (Östberg, 1973; Reinberg, 1974; Ehret, Meinert and Groh, 1978); (2) the central role of catecholamine (awake) and indoleamine (asleep) pathways in clock chemistry, and their stimulation by either high protein meals (Ehret, Meinert and Groh, 1978; Lemmer and Wenda, 1978; Akerstedt and Froberg, 1979) or by high carbohydrate meals, respectively; (3) the chronobiotic action of mild drugs, including the methyl xanthines (caffeine, theophylline, theobromine) (Ehret, Potter and Dobra, 1975; Mayer and Scherer, 1975); and (4) the use of social cues as zeitgebers. These techniques taken altogether strongly reinforce the point already made by Folkard, Monk and Lobban (1978) who concluded that the life-style resulting from total commitment to shift work, including rigorous adherence to self-imposed schedules, "produced significant changes in the degree to which various physiological and psychological rhythms adjusted." Successful application of the Argonne developed techniques in human studies on jet lag have already been reported in two studies of U.S. military personnel in transatlantic flight to Germany (Graeber, Cuthbert, Sing, Schneider, and Sessions, 1979; Cuthbert, Graeber, Sing, and Schneider, 1979). These circadian chronohygiene techniques are adapted and consolidated for the shift worker in Fig. 2 (for phase advance scheduling) and

| THU<br>Old Shift | FRI<br>Last Day, Old Shift | SAT<br>Day Off | SUN<br>Day Off | MON<br>New Shift |
|---|---|---|---|---|
| ROUTINE | FEAST | FAST<br>(see below) | BREAK-THE-FAST<br>NEW TIME | ROUTINE |

| Day Off #1<br>SATURDAY<br>Old Time | | Chronophase Advance<br>← 8 hours → | Day Off #2<br>SUNDAY<br>New Time | |
|---|---|---|---|---|
| MORNPHASE | EVENPHASE | MORNPHASE | NOONPHASE | EVENPHASE |
| •Eat sparingly<br>•Avoid carbohydrates (fruit OK)<br>•No coffee or tea unless decaff | •Several cups of black coffee<br>•No cream, sugar, or snacks<br>NOONPHASE<br>•Eat sparingly | •Lights on, exercise<br>•Big high-protein breakfast<br>•No caffeine | •Big high-protein lunch | •High-carbohydrate/low-protein supper<br>•Early to bed |

Fig. 2. Chronohygiene for Advance Rotation: A diet plan to implement circadian phase advance during slow rotation.

Fig. 3 (for phase delay scheduling). On "feast" days, 3 full meals are eaten, preferably a high protein breakfast and lunch (to stimulate the catecholamines and wakefulness) and a high carbohydrate supper (to stimulate the indoleamines and sleep). On "fast" days, 3 small meals are permitted, all low in carbohydrates and in calories, to encourage glycogen depletion (Ehret, Meinert and Groh, 1978). The fast is broken by taking breakfast during "mornphase" of the *new* shift schedule, and the meal consists of high protein, again to stimulate catecholamine systhesis. Subsequent meals resemble those to be followed routinely in mornphase, noonphase, and evenphase on subsequent shift days (Fig. 4). Methylated xanthine beverages (coffee, tea, cocoa, colas ) are routinely avoided mornphase and evenphase, but permitted and encouraged after noonphase ("teatime"); taken then, these beverages cause neither phase advance nor phase delay, and may enhance stable euchronism (Ehret, Meinert and Groh, 1978). Taken *after* evenphase they encourage the phase advance desired in shifts employing Fig. 2; taken after mornphase and before noonphase, they encourage the phase delay desired in shifts employing Fig. 3.

| THU<br>Old Shift | FRI<br>Last Day, Old Shift | SAT<br>Day Off | SUN<br>Day Off | MON<br>New Shift |
|---|---|---|---|---|
| ROUTINE | FEAST | FAST<br>(see below) | BREAK-THE-FAST NEW TIME | ROUTINE |

| Day Off #1<br>SATURDAY<br>Old Time | | Chronophase Delay<br>→ 8 hours → | Day Off #2<br>SUNDAY<br>New Time | |
|---|---|---|---|---|
| MORNPHASE | EVENPHASE | MORNPHASE | NOONPHASE | EVENPHASE |
| •Sleep late<br>•Several cups of black coffee or tea | •Eat sparingly<br>•Avoid Carbohydrates (light salads, fruit OK)<br>•No coffee or tea unless decaff | •Lights on, exercise<br>•Big high-protein breakfast<br>•No caffeine | •Big high-protein lunch | •High-carbohydrate/low-protein supper<br>•To bed on new time |

Fig. 3. Chronohygiene for Delay Rotation: A diet plan to implement circadian phase delay during slow rotation.

| MORNPHASE | | NOONPHASE | | RESTPHASE | | EVENPHASE | |
|---|---|---|---|---|---|---|---|
| *m* | 0700 | *m* | 1200 | *m* | 1530 | *m* | 1800 |
| *a* | 1500 | *a* | 2000 | *a* | 2330 | *a* | 0200 |
| *n* | 2300 | *n* | 0400 | *n* | 0730 | *n* | 1000 |

| BREAKFAST | LUNCH | TEATIME | SUPPER |
|---|---|---|---|
| •Lights on<br>•Exercise<br>•Big, high-protein breakfast<br>•No caffeine | •No naps<br>•Big, high-protein lunch<br>•No caffeine | •Coffee, tea or cocoa<br>•Sweets | •High carbohydrate, low protein<br>•No caffeine<br>•Low-key exercise |

Fig. 4. Chronohygiene for the Routine Workday: A guide to an orthochronally proper daily routine for the shift worker on the morning (*m*), afternoon (*a*), or night (*n*) shift. The times that are given in the table are approximate (± 1 h), but conform in principle to the preferred "7-15-23" system (Östberg, 1973).

## DISCUSSION

In engineering out the risks that society suffers from its dyschronic shift workers, or that shift workers themselves suffer, several studies cited above have already shown that multiple zeitgeber chronohygiene techniques are effective. These techniques can dramatically accelerate phase-shift transients of physiological and psychometric performance to the norm within 2 or 3 days (Graeber, Cuthbert, Sing, Schneider, and Sessions, 1979), that might otherwise have taken 10 to 14 days to accomplish (Folkard, 1980). Strategies to compensate for performance deficits when a crew of operators is large enough include the use of an "advance party" method, in which only half of a relief crew arrives at work to rotate into its new shift; of course half of the old seasoned crew remains behind for 2 days, assuming not only seniority in critical decision-making, but also providing an input of active-phase social cues appropriate to their chronophase; the latter are then relieved 2 days later by the "rear party" of the crew. The techniques require shift tenures of >> 1 week to be effective, and present evidence suggests that the results can be improved considerably by dedication to appropriate shift chronohygiene schedules even on off days (e.g., Figs. 2 and 3). Worker indoctrination and monitoring methods, and parallel experimental approaches with animal models are currently under active development and study.

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Mr. **Gore**. Thank you. That was really fascinating.

Let me ask one quick question, and then I want to recognize my colleague.

When you say caffeine resets the body clocks, we heard yesterday that the definition of that word "reset" means really not setting it back to zero but altering it within an hour forward or backward.

Can you help me understand your definition of the word "reset"?

Dr. **Ehret**. Yes. By that I mean that we can in fact cause a phase shift by getting a phase advance or a phase delay, just as we would on our wristwatch. But in all oscillating systems, including electrical oscillations, we have what we would call a phase response curve that is generated.

If I can draw it in the air, I would say that there is a certain time in the cycle at which if you strike with the zeitgeber you do not reset the clock. Still later, you reset the phase delay. Still later, to even more phase delay. Still later, to even more phase delay. Later than that, not any more phase delay but instead you get phase advance and less phase advance and then you are back to no effect.

So, it is a curve that has a very strange shape to it. It is a portion of what we could call a limit cycle resetting function. You may predictably reset the clock by 1 hour or 2 hours or 6 hours with one shot of a zeitgeber.

Mr. **Gore**. Six hours?

Dr. **Ehret**. Within one shot you can predictably reset—the most rapid resetting that we know of biological clocks is from cellular studies, and that would be within a day, three-quarters of a day at the shortest. So, if this takes a millisecond, the biological clock will never be much shorter than something like three-quarters of a day, a major fraction of the circadian cycle.

Mr. **Gore**. Wait a second. Help me understand this. Let's take someone whose body clock is attuned to what we call a normal workday. Let's make it 8 o'clock in the morning until 5 o'clock in the afternoon. That person is normally going to get sleepy and go to bed at 11 o'clock and get up at 6:30 or 7.

You are saying that curve would look something like this through the day.

Dr. **Ehret**. That is what we call a phase response curve, yes.

Mr. **Gore**. You are saying that some of these resetters—what is your German word?

Dr. **Ehret**. Zeitgeber. It is an English word now. It is in the Post. It is a good one to learn.

Mr. **Gore**. Let's take caffeine as an example of a zeitgeber. You are saying that the effect of that zeitgeber on that person's biological rhythm will be different in the morning than in the afternoon or in the evening?

Dr. **Ehret**. Exactly.

Mr. **Gore**. Specifically, a lot of caffeine in the morning on that rhythm does what to that person's body clock?

Dr. **Ehret**. It resets the clock to what we call circadian phase delay. I think there was a confusion of terminology in the past 2 days about terms. I think that has to be cleaned up. The standard term would be phase delay. A good way to remember that is that that is like flying to San Francisco.

Mr. **Gore**. That is not a good way for me to remember it.

Dr. **Ehret**. Well, like flying to Honolulu.

Mr. **Gore**. That is not a good way for me to remember it, either.

Dr. **Ehret**. Well, as Horace Greeley says, "Go west, young man."

Mr. **Gore**. That person's body clock is telling that person to wake up at 6:30 in the morning. If that person goes through a normal day, has a heavy dose of caffeine in the morning and there are no other zeitgebers for the rest of the day, is that person going to tend to wake up at 6 o'clock in the morning the next day or 7 o'clock in the morning the next day?

Dr. **Ehret**. Later, and it may be as late as 10 o'clock in the morning. It depends upon the dose, it depends upon the time of delivery.

Mr. **Gore**. So, a phase delay would mean that the times in the cycle would advance?

Dr. **Ehret**. Yes. I think a good way to remember it, in the ROTAS of the world we have the graveyard ROTA and other sorts of terms around the world that are equivalent to this. I think there is a tendency now to get on to the morning shift, the afternoon shift and the night shift.

A good memory device here is that M-A-N is what we have been talking about as the correct way to go. It spells MAN. You should go from the morning shift to the afternoon shift, from the afternoon shift to the night shift, because in effect the biological clock is a 25-hour clock. That is phase delay in the biological clock in all of the conventional terminology.

Mr. **Gore**. Help me out here. That same person, caffeine in the afternoon will have the same effect or a different effect?

Dr. **Ehret**. No, it doesn't. Let's go to late at night. Late at night it causes a phase advance, as if you were flying to Paris or if you wanted to get up earlier in the morning.

Middle afternoon we call it British tea time, pneumonic device or the memory device. That is the right time to have caffeinated beverages if you are concerned about your clock, because it is neither phase advance nor phase delay. In fact, zeitgebers of this sort would tend to make more coherent all of the billions of clocks that might be mavericks getting out line, so it may in fact be a very healthy procedure to have this coffee break midafternoon.

We have a hospital in our town run by Seventh Day Adventists. They advocate laying off things like alcohol and coffee completely. We usually say you should live like a Seventh Day Adventist, except in the afternoon you should live like an Englishman or a heathen.

Mr. **Gore**. Congressman Durbin?

Mr. **Durbin**. Forgive me if I struggle along with some of the terminology, too. I will try to make the question intelligible in my own struggling fashion.

I assume that an ordinary human being, a normal person, has certain physiological variables, such as the diurnal temperature cycle that vary on a chronological basis, assuming no external drugs or anything like that. Is that correct?

Dr. **Ehret**. I think one of the points I might have brought up, had I had the time, is in fact the depths on the line. I guess in the studies of the past 35 years, about 15 years ago the studies of chronotype came in, which is extraordinarily important. It is linked to the notion of the genetic phenotype. You are a redhead or a blonde, you have brown eyes or blue eyes. That is something we know about.

Suppose you were a blonde at noon and a redhead at midnight without using Clairol. That is something like the notion of chronotype, and it is not happening because this is already dead and gone. In the body, in effect, every cell in the body is experiencing changes as dramatic as that.

The enzymatic content, the nucleic acid content, the hormonal content of the system are quite distinctively different. The manifestation of this, or the things we heard about yesterday in terms of gross observations such as sleep or don't sleep, be awake or don't be awake, be active or be inactive, have high temperature or have low temperature, all of these are simply reflections of the enzymatic changes that involve a program which say that if a specific enzyme comes on early, another one is programed to come on later and another still later.

Literally, we are a different people biochemically at 4 in the morning and 6 in the morning than we are at 6 in the afternoon.

Mr. DURBIN. But the natural human function is to have some type of consistent program among all human beings?

Dr. EHRET. If you are healthy.

Mr. DURBIN. What about a person who has worked the night shift for a long period of time? Is his program changed because of that experience?

If such a person went into the hospital and experienced a high temperature, would the attending physician and nurse note that that temperature was spiking at a period of time when it ordinarily wouldn't in a person who had a regular day shift?

Dr. EHRET. That requires a rather lengthy answer. We know a little bit, and there is a whole lot which we don't know that requires further work. What we know has to do with, for example, a category called the ex-shift worker, the person who couldn't handle shift work and therefore went off it. These people are different categorically in certain ways.

We don't know really, for example, whether—the studies go back to the baking industry in Germany at the turn of the century. Here a lot of these bakers were prime candidates to go into the mental institutions. They became institutionalized on account of neuroses and psychoses.

Those that became good bakers apparently had their entire biological clock turned around very well, so that the hormones of the adrenal cortex were coming on around midnight instead of around 8 in the morning and everything was flipped around.

What happened to them when they went off work, later on, we don't know. We know such things as Dr. Goldstein mentioned a while ago that perhaps a short time after retirement the probability of death may be increased.

Mr. DURBIN. I am trying to reach a conclusion as to whether it would not be healthier in the long run for a person to stay on the same shift indefinitely rather than a move from shift to shift.

Dr. EHRET. That again has a lengthy history. For example, dedicated shifts, sometimes—for example, we can consider a show business performer on stage in Las Vegas at 11 o'clock at night. If she is not a drug addict or an alcoholic, chances are she is pretty healthy. Chances are that on weekends she doesn't sunlight, she stays a night person. That is true dedication all the way.

If the dedicated shift worker is flipping back again, always to daytime recreation, then there is a problem because then he or she is still resetting his clock. Dedication in itself doesn't solve the problem.

Furthermore, industry doesn't like dedicated shifts. Commonwealth Edison is trying to eliminate dedicated shifts because they can't promote workers. Their best young men, in order to be promoted, have to be promoted upstairs to a worse shift. They would rather not be promoted and stay on a better shift.

Mr. **Durbin**. Dr. LeClercq, I would like to ask you, from some of your studies on the industry viewpoint, did you take into account at all white-collar creativity? We talked a lot about the impact on a person who is on his feet, the blue-collar worker and so forth. What about that aspect of it rather than just clerical work or moving paper; not just the administrative function, but the actual creative function. Has there been any study in your industry in this aspect?

Dr. **LeClercq**. Not with regard to shift work. Generally speaking, white-collar folks don't work shift work. When they do, it is the type that you are personally aware of; it is the 12-hour, 6-day, year-in and year-out. But they do not go on rotational shift work.

We are addressing ourselves for the most part to process operators in the chemical plants, who would be termed as blue-collar workers.

Mr. **Durbin**. Dr. Goldstein, although I've had little exposure to police work, it seems the hottest time of the day for the policeman is usually at night, that period from 9 o'clock until 2 or 3 in the morning. Has that been your experience?

Dr. **Goldstein**. Do you mean when they are most busy, most calls for service?

Mr. **Durbin**. When they are subject to the most stress; when they are called into service.

Dr. **Goldstein**. Most calls for service I think in our county, and maybe Paul can correct me if I am wrong, come somewhere between the evening hours, like 6, 7, or 8 o'clock at night, up until about 2 in the morning.

We are finding a very dangerous time, it seems, is right after that, from 2 until 3 in the morning, anywhere I guess past 1 o'clock in the morning. So, there is some problem with that. We do see that there seems to be some higher assaults on police, as I mentioned before, during that particular phase.

Mr. **Durbin**. Let's assume for our discussion here we are talking about 8-hour periods, roughly, 6:30 to 2:30, where there is real stress, calls are being made, and decisions have to be made on the spot.

Do you break your shift in that 8-hour period?

Dr. **Goldstein**. Our particular shift is a 10-hour shift. We have a layover of shifts during that time. They work 10 to 2 and another shift comes on at 12 o'clock, so there is actually double manpower.

Mr. **Durbin**. Twelve o'clock midnight?

Dr. **Goldstein**. Twelve o'clock midnight.

Mr. **Durbin**. Do you see any changes there as one shift is finishing 10 hours and another is starting as to some of the symptoms that you have noted here?

Dr. **Goldstein**. This is what we are going to be studying in our shift plan study. To our knowledge, there hasn't been any real study of that particular thing. Each department has very different shift plans.

As Dr. Ehret pointed out, these things are tradition-bound, they are willy-nilly planning. A lot of them are organized around payroll schedules, a lot of them are organized specifically around manpower, but with no real look at what having the manpower on that street, if it is effective or if it is in fact damaging to the police officer on the job. So, that is what we are going to be looking at, that very question.

Mr. **Durbin**. Dr. Ehret, can I assume for a person exposed to some moderating or calming factors that these factors will have an impact on their own body clock, a quiet environment, a dark environment, something of that nature?

Dr. **Ehret**. I think so. One views, for example, the example I gave about the Florida beach. You don't want light in your bedroom at 3 in the morning. In the well-lived high quality of life one recognizes what the multiple "zeitgebers" are and brings them into phase harmony.

If you bring any one of these or several of these out of harmony, if instead of having programed feeding you become a nibbler, or as we see in the power industry and in the firehouses, the kitchen is the center of activity. There is always a spaghetti dinner going on, there is always the coffee pot brewing, there are always the caffeinated beverages and tin cans sitting around on the benches. What one has here is a capricious and a continuous, a chronic stimulation.

If you take a zeitgeber in a punctate fashion, you can reset predictably the biological clock, just as we do with thumb and forefinger. If you take it chronically, you generate a condition that we call dyschronism. It might be internal desynchronization, as we heard about yesterday. It might be splitting or it may be entire wave form flattening. All of these are associated with what is now known as a direct correlative, the effective disorders that Dr. Wehr spoke a bit about yesterday.

Mr. **Durbin**. I guess my point is the antithesis. Instead of being exposed to a stimulus a person is exposed to a quiet environment every day when they go to work: A museum guard stands there and no one is supposed to speak; it is a hushed room and it is dark. Does that have any impact on his biological rhythms?

Dr. **Ehret**. It might or it might not. I guess it depends upon his own intellectual style. We advise people when they arrive in Paris not to hole up in the hotel room and eat their breakfast alone. We advise conviviality.

Social cues ought to be taken in the middle of the active phase. The more the better. I think the guard in the museum, if he is solving logarithms like an idiot savant, that might amuse him and keep his brain active. I don't know.

Mr. **Durbin**. Thank you. That is all I have, Mr. Chairman.

Mr. GORE. Back to these zeitgebers for just a second. Your understanding of these zeitgebers is based principally on rodent studies?

Dr. EHRET. It is based upon literature in the field at large and in my own laboratory, studies on rodents. There have been a lot of spinoffs, studies of humans, for example, in Dr. Weitzman's laboratory in White Plains, N.Y., formerly the Montefiore Hospital where Dr. Czeisler did his work, and also at an institute southwest of Munich run by Jurgen Ashov. These are the principal sources of the human understandings of the operation of the human biological clock.

Mr. GORE. But it might well be that the specific effect of specific zeitgebers at specific times during the cycle would be different for diurnal mammals than for nocturnal rodents?

Dr. EHRET. That has to be looked at very carefully up and down the board, right.

Mr. GORE. The caffeine example which I cited happens to be one based on rodent work?

Dr. EHRET. That was used in conjunction with multiple zeitgebers in a very large-scale study out of Walter Reed. Preceding that study we had a lot of anecdotal responses, I would say by the thousands. Up to now we have over 60,000 responses from various people, which is quite a large number, but they are mostly anecdotal.

If you go down through the history behind the human studies, in resetting the clock for jet lag, using the zeitgebers you are talking about, they included a group, the Automotive Transportation Supervisors of Chicago, who had meetings in Zurich and London and Honolulu, and they used the multiple zeitgeber method. They gave back questionnaires, and a few of these were quite thorough.

They impressed Major Graeber of the Walter Reed group so much that they decided that they should launch the largest scale human investigation. They did this with elements of the Second Armored Division, the First Infantry Division in NATO exercises, going from Texas and from Kansas over to Germany.

Here there was a very distinct advantage. The studies in this case, unlike the anecdotal ones, included something like a double blind. They included people being given the wrong as well as the right diet. The wrong was no worse than the airlines would have treated you anyway.

Mr. GORE. Speaking of NATO, I am told that our negotiators in the State Department typically go to Europe to meet with their NATO counterparts and Common Market negotiators, get off the plane, prepare their work, go into the meetings at the low point on their cycles and come up with the Memoranda of Understanding when they are least alert and least functional.

Is anybody familiar with that?

Dr. EHRET. I think the classical study which we cite in our book, which is coming out next month, is that of John Foster Dulles' regrets, a deathbed confession, in effect, about his negotiations with the Egyptians on the Aswan Dam. He attributed this especially to jet lag discombobulation.

Of course, that is an anecdotal report. Whether it was the case or not is another matter. It looks very much like it.

Mr. GORE. Dr. Goldstein, are you planning to use the study you have underway to design better work schedules? Are you actively anticipating a completely different work schedule when your study is complete?

Dr. GOLDSTEIN. We believe that the preliminary results of our pilot study will then give us—we are going to walk before we run on this. The pilot study currently is not what we consider to be the best or ideal shift schedule but again, noting the political climates of the institution itself and some of the ingrained patterns, we are going to try to go midway between perhaps what we see as ideal and prove the benefits to the department and to the families of the workers there, and then maybe move on to another pilot study from there.

Mr. GORE. Thank you.

Dr. LeClercq, you indicated that Exxon management has generally reacted positively to the idea of scientifically selected ROTAS, to use Dr. Ehret's word. Have you had that kind of cooperation with management?

Dr. LECLERCQ. That is correct.

Mr. GORE. No resistance?

Dr. LECLERCQ. As you mentioned yesterday, they perceive it the same way we perceive it, which is the same way our workers perceive it, as a very real WIN-WIN situation.

Mr. GORE. Very good.

Congressman Reid?

Mr. REID. I have no questions, Mr. Chairman.

Mr. GORE. I have found this panel very fascinating. I appreciate your help here. We will be back in touch with you as we prepare our report. Thank you very much.

Dr. GOLDSTEIN. Thank you.

Mr. REID [presiding]. We will call for the third panel of today's testimony those people representing two federal agencies: Dr. H. L. Reighard and Hugh Thompson. Dr. Rieghard is the Federal Air Surgeon with the Federal Aviation Administration, and Mr. Thompson is with the Division of Human Factors Safety, Office of Nuclear Reactor Regulation, United States Nuclear Regulatory Commission.

I have only read off two names and I see three of you.

Mr. THOMPSON. I cleverly have with me Dr. Dan Jones, who is our Program Manager for the Human Factors Developmental Programs, as I indicated in my testimony.

Dr. REIGHARD. I have with me Dr. Carl Melton, who is Chief of our Aviation Physiology Laboratory at Oklahoma City.

Mr. REID. Dr. Melton, you are welcome to come forward, if you would like, and join your colleague at the table.

Dr. Reighard, will you please proceed.

[The biographical sketch of Dr. Reighard follows:]

October 1981

## CURRICULUM VITAE

Reighard, Homer L., M.D., M.P.H., B.S.
10215 Hatherleigh Drive
Bethesda, Maryland 20014
Telephone: 530-0586

BORN: December 1, 1924
Martinsburg, Pennsylvania

### EDUCATION AND TRAINING:

B.S., cum laude 1945 - Franklin and Marshall College
M.D., 1948 - Temple University School of Medicine
Internship, rotating, 1948 - 1949 - Temple University Hospital
U. S. Air Force School of Aviation Medicine, October - December 1950
Aircraft Accident Investigation Course, University of Southern California - 1959
M.P.H. 1961 - Harvard School of Public Health
FAA Executive School - June 1967
Federal Executive Institute - February - March 1972

### EMPLOYMENT:

Physician-in-Charge, Accidents Dispensary, Temple University Hospital, 1949 - 1950.
Flight Surgeon, U. S. Air Force, 1950 - 1953
General Practice of Medicine, 1953 - 1960
Aviation Medical Officer, Civil Aeronautics Administration, 1953 - 1956
Chief, Medical Standards Branch, Medical Division, Civil Aeronautics Administration, 1956 - 1959
Chief, Medical Standards Division, Aviation Medical Service, Federal Aviation Agency, 1959 - 1962
Special Assistant for Professional Programs, Staff of Civil Air Surgeon, Federal Aviation Agency, 1962 - 1963
Acting Civil Air Surgeon, March 1963 - October 1963
Acting Deputy Federal Air Surgeon, October 1963 - August 1964
Deputy Federal Air Surgeon, August 1964 - March 1975
Federal Air Surgeon, March 1975 - present

### SPECIAL EMPLOYMENT ACTIVITIES:

Chairman, Medical Study Group, International Civil Aviation Organization, 1967, 1968, 1969 and 1970
U. S. Medical Representative, ICAO Personnel Licensing, Training and Medical Division Meeting, 1970
Chairman, Task Force on Deterrence of Air Piracy, February 1969 - August 1970

## SPECIALTY CERTIFICATION:

Diplomate, American Board of Preventive Medicine in Aviation Medicine

## MEMBERSHIPS IN PROFESSIONAL ORGANIZATIONS:

Associate Member, American Medical Association
Associate Member, Medical Society of the District of Columbia
Fellow, Aerospace Medical Association
Member, Scientific Program Committee, Aerospace Medical Association, 1963
Member, Scientific Exhibits Committee, Aerospace Medical Association, 1959 - 1961
Member, Long-Range Planning Committee, Aerospace Medical Association, 1961 - present
Member, Subcommittee on Airport Medical Services, American Medical Association, 1961 - 1962
Member, Scientific Program Committee, Aerospace Medical Association, 1970 - 1972

## COMMUNITY ACTIVITIES:

- Local PTA
  - Trustee 1968 - 1970
  - President 1970 - 1971
  - County Delegate 1971 - 1972
- Community Swimming Pool Association
  - Member, Board of Directors, 1968 - present
  - Chairman, Administrative Committee, 1971 - 1973
- Boy Scouts
  - Assistant Scoutmaster, 1974 - present

## HONORS AND AWARDS:

Member, Phi Beta Kappa
Meritorious Service, FAA, 1970
Harry G. Moseley Award, Aerospace Medical Association, 1977

## PUBLICATIONS:

Comparison of Ballistocardiographic Systems ..., Amer. Journ. Cardiol., 4:2, 232 - 239, 1959 (Co-author)
Medical Services at Airports, Amer. Med. Assoc., Arch.of Environ. Health, Vol. 5, 344 - 357, 1962
Some Aspects of Sudden Incapacitation in Airmen ..., Aerospace Medicine, 38:12, 1273 - 1275, 1967
U. S. Aircraft Hijackings - Epidemiological Considerations, Recent Advances in Aerospace Medicine, Proceedings XVIII International Congress of Aviation and Space Medicine, Amsterdam, 1969, 130 - 134

## PUBLICATIONS (Continued):

FAA-AM-78-35 Task Force on Deterrence of Air Piracy--Final Report

## FAMILY:

Wife - Barbara
2 daughters
1 son

## STATEMENTS OF H. L. REIGHARD, FEDERAL AIR SURGEON, FEDERAL AVIATION ADMINISTRATION, ACCOMPANIED BY CARL MELTON, CHIEF, AVIATION PHYSIOLOGY LABORATORY, OKLAHOMA CITY; AND HUGH THOMPSON, DIRECTOR, DIVISION OF HUMAN FACTORS SAFETY, OFFICE OF NUCLEAR REACTOR REGULATION, NUCLEAR REGULATORY COMMISSION, ACCOMPANIED BY DANIEL B. JONES, PROGRAM MANAGER, HUMAN FACTORS DEVELOPMENTAL PROGRAMS

Dr. REIGHARD. I appreciate the opportunity to appear before the subcommittee today to discuss circadian rhythms and their effect on FAA employees who are called upon to work rotating shifts.

The potential for circadian disruption, or desynchronosis, has been of long-standing interest to the FAA because many of our workers must work rotating shifts in order to provide aviation services on a round-the-clock basis.

Consequently, for over 20 years FAA has undertaken research at its Civil Aeromedical Institute, CAMI, to define and quantify the physiological and performance effects of circadian disruption on shift workers.

Our research work has predominately centered around our air traffic controller work force, but the conclusions we draw from that work can essentially be applied to our airway facility technicians, who are also called upon in many cases to work shift work.

Although there are a variety of shifts worked by our controller work force, there are two basic rotation patterns. One rotation calls for two 5-day, 40-hour weeks on the evening shift; 2 weeks, 5 days each, on days; and 1 week on the midnight shift. This pattern is referred to as the straight 5. Each work day is 8 hours long and work days are separated by 16 hours off duty.

The second basic shift pattern is one that calls for a work week consisting of two consecutive evening shifts, then 2 day shifts, and finally 1 midnight shift. The controversial feature of this latter rotation, which is called the "2-2-1" or 'rattler,' is that no two work periods are separated by 16 hours. The longest separation is 14 or 15 hours and the shortest is 9 or 10 hours.

These quick turnarounds result in compression of the 40-hour work week into an 88-hour period, leaving 80 hours, or 47 percent of the 7-day week, off duty between work weeks. For this reason, we have found that the 2-2-1 is the shift pattern preferred by most controllers.

Many FAA managers have traditionally believed that the quick turnaround feature of the 2-2-1 shift pattern was excessively stressful because of a reduced opportunity for sleep. Biochemical and physiological measurements taken during the research we have conducted, however, simply do not bear this out.

These biomedical studies do not point to either one of these work patterns as being superior to the other. Moreover, surveys we have taken show no significant difference between them with regard to quantity of sleep. They do indicate, however, that our controllers' greatest preference is for day work and the least preference is for the midnight shift.

The 2-2-1 is preferable to many of our controllers, in that regard, since many controllers seldom work the midnight shift because of the reduced staffing on that light traffic shift or because of shift trading. Moreover, when that shift is worked, it is followed by the extended off-duty period. We have found, though, that some controllers will choose the midnight shift not because they like it but because they want to be off duty during the daytime.

In short, then, we have not found any stress indicators which say that one shift is better than another, nor is there any medical evidence that is persuasive concerning the desirability of one shift pattern over another. Neither have we seen any indications of diminished work performance based upon the kinds of shifts worked.

We do know that many of our controllers and airway facility technicians would like a straight day shift, but it is not always possible to arrange that schedule because aviation operational considerations frequently require a 24-hours a day, 7-days a week effort by the FAA.

We also know that worker satisfaction seems to be the highest when they can participate in choosing their work schedule and, consistent with mission requirements, we seek to provide them that opportunity for input.

Since no medical evidence has been developed which indicates that one type of rotating shift is preferable to others, FAA has established no "standardized shift" that must be followed throughout the country. Instead, decisions are made at the facility level on the types of shifts to establish.

Employees are provided numerous means of input into these shift scheduling determinations. For example, facility advisory boards have been established to provide worker input to agency management on the full range of issues affecting the air traffic work force. Union agreements typically provide as well for worker input into shift development.

Also worth noting is the fact that over the last several months we have been making a number of technical additions and changes to the agency order on work weeks and hours of duty.

Consistent with the FAA human relations program, recently initiated by the Administrator, we have changed the order to re-emphasize to regional and facility management the importance of seeking worker input, consistent with operational needs, when considering changes to shift scheduling practices.

Our research tells us that worker participation in developing the work schedule—and not the type of schedule itself—is the key factor in fostering worker satisfaction and a productive work environment.

Significantly, many of our workers appear to be guided more in their shift choices by the time they want off from work rather than by the hours they want to work, thus accounting for the popularity of the 2-2-1 rotation.

Regardless of the subjective reasons for choosing one shift over another, we believe our employees' feelings about the the shifts to which they are assigned are important and to the extent feasible they should have a say in shaping the schedules they are to work.

That completes my prepared statement, Mr. Chairman. I would be pleased to respond to questions.

[The prepared statement of Dr. Reighard follows:]

## STATEMENT OF H. L. REIGHARD, FEDERAL AIR SURGEON, FEDERAL AVIATION ADMINISTRATION, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT, CONCERNING THE EFFECT OF SHIFT WORK ON FEDERAL AVIATION ADMINISTRATION EMPLOYEES. MARCH 24, 1983.

Mr. Chairman and members of the subcommittee; I appreciate the opportunity to appear before the Subcommittee today to discuss circadian rhythms and their effect on FAA employees who are called upon to work rotating shifts. The potential for circadian disruptions—or desynchronosis—has been of longstanding interest to the FAA because many of our workers must work rotating shifts in order to provide aviation services on a round-the-clock basis. Consequently, for over 20 years, FAA has undertaken research at its Civil Aeromedical Institute (CAMI) to define and quantify the physiological and performance effects of circadian disruption on shift workers.

Our research work has predominantly centered around our air traffic controller workforce, but the conclusions we draw from that work can essentially be applied to our airway facility technicians who are also called upon in many cases to work shift work.

Although there are a variety of shifts worked by our controller workforce, there are two basic rotation patterns. One rotation calls for two 5-day (40 hour) weeks on the evening shift, 2 weeks on days, and 1 week on the midnight shift. This pattern is referred to as the "Straight 5." Each workday is 8 hours long and workdays are separated by 16 hours off duty. Workweeks are separated by 2 days off. The second basic shift pattern is one that calls for a workweek consisting of 2 consecutive shifts, then 2 day shifts, and, finally, 1 midnight shift. The controversial feature of this latter rotation, which is called the "2-2-1" or "rattler," is that no two work periods are separated by 16 hours. The longest separation is 14 or 15 hours and the shortest is 9 or 10 hours. These quick turnarounds result in compression of the 40 hour workweek into an 88 hour period, leaving 80 hours (or 47% of the 7 day week) off duty between workweeks. For this reason, we have found that the 2-2-1 is the shift pattern preferred by most controllers.

Many FAA managers have traditionally believed that the quick turnaround feature of the 2-2-1 shift pattern was excessively stressful because of a reduced oportunity for sleep. Biochemical and physiological measurements taken during the research we have conducted, however, simply do not bear this out. These biomedical studies do not point to either one of these work patterns as being superior to the other. Moreover, surveys we have taken show no significant difference between them with regard to quantity of sleep. They do indicate, however, that our controllers' greatest preference is for day work, and the least preference is for the midnight shift. The 2-2-1 is preferable to many of our controllers, in that regard, since many controllers seldom work the midnight shift because of the reduced staffing on that light traffic shift or because of shift trading. Moreover, when that shift is worked, it is followed by the extended off-duty period. We have found, though, that some controllers will choose the midnight shift not because they like it but because they want to be off duty during the daytime.

In short, then, we have not found any stress indicators which say that one shift is better than another, nor is there any medical evidence that is persuasive concerning the desirability of one shift pattern over another. Neither have we seen any indications of diminished work performance based upon the kinds of shifts worked. We do know that many of our controllers and airway facility technicians would like a straight day shift, but it's not always possible to arrange that schedule because aviation operational considerations frequently require a 24 hours-a-day, 7 days-a-week effort by the FAA. We also know that worker satisfaction seems to be the highest when they can participate in choosing their work schedule, and, consistent with mission requirements, we seek to provide them that opportunity for input.

Since no medical evidence has been developed which indicates that one type of rotating shift is preferable to others, FAA has established no "standardized" shift that must be followed throughout the country. Instead, decisions are made at the facility level on the types of shifts to establish. Employees are provided numerous means of input into these shift scheduling determinations. For example, facility advisory boards have been established to provide worker input to agency management on the full range of issues affecting the air traffic workforce. Union agreements typically provide as well for worker input into shift development.

Also worth noting is the fact that over the last several months we have been making a number of technical additions and changes to the agency order on workweeks and hours of duty. Consistent with the FAA human relations program, recently initiated by the Administrator, we have changed the order to reemphasize to regional and facility management the importance of seeking worker input, consistent with operational needs, when considering changes to shift scheduling practices. Our research tells us that worker participation in developing the work schedule—and not the type of schedule itself—is the key factor in fostering worker satisfaction and a productive work environment. Significantly, many of our workers appear to be guided more in their shift choices by the time they want off from work rather than by the hours the want to work, thus accounting for the popularity of the 2-2-1 rotation. Regardless of the subjective reasons for choosing one shift over another, we believe our employees' feelings about the shifts to which they are assigned are important, and that, to the extent feasible, they should have a say in shaping the schedules they are to work.

That completes my prepared statement, Mr. Chairman. I would be pleased to respond to questions you may have.

Mr. REID. We will ask questions after we hear from Mr. Thompson.

Mr. Thompson?

Mr. THOMPSON. Thank you, Mr. Chairman.

I think I am suffering from one of the health effects of the shifting seasons as opposed to shifting schedules, but if you will bear with me, I will continue.

The NRC is pleased to have this opportunity to participate in the hearing today, addressing the problems of biological rhythms and shift-work scheduling.

As you know, NRC is responsible for insuring public health and safety in nuclear powerplant operations. The division of human factors safety is relatively new to the NRC, having been created approximately 3 years ago. That was one of the internal activities NRC undertook in response to the accident at TMI.

The division addresses all of the human factors safety activities related to nuclear powerplant operation, including the control room design review, the staffing, qualification of operators, training, including the operator examination, as well as items such as shift scheduling.

As you know, nuclear powerplants operate on a 24-hour-a-day basis, 7 days a week. Thus, shift work is a way of life for these operators and other key personnel. NRC's concern is with operator performance under stress—that is, during an unplanned, abnormal, or emergency condition—and with the operator's ability to maintain the plant in a safe condition.

The issue of shift scheduling and overtime, and their relationship to plant safety, has gained increased attention since the accident at Three Mile Island. In response to the Three Mile Island action plan, NRC has issued Generic Letter 82-12, dated June 15, 1982. Earlier versions of this policy statement were issued as early as February 1980.

This commission policy statement provides guidance for overtime work for plant staff who perform safety-related functions; that is, the senior operators, the plant operators, the auxiliary operators, and some other key people, such as the health physicists and key maintenance personnel.

The policy statement calls for operating plants to have adequate staff coverage so that routine, heavy use of overtime is not needed. In unusual circumstances, deviations from the guidelines, which are set out in the policy statement, may be authorized on a temporary basis by the plant manager, his deputy, or higher management.

The document does not lay down any specific guidance for the shift schedule itself. It does specify that no individual should be permitted to work more than 16 hours straight, excluding shift turnover time; that no individual should be permitted to work more than 16 hours in any 24-hour period, nor more than 24 hours in any 48-hour period, nor more than 72 hours in any 7-day period, all excluding the shift turnover time; a break of at least 8 hours is to be provided between work periods; and except during extended shutdown periods, the use of overtime should be considered on an individual basis, and not for the entire staff or shift on crew.

The intent here is to prevent situations where fatigue could reduce the ability of the operating personnel to keep the reactor in a safe condition.

NRC is aware of the inherent problems in shift work. In 1980 we had an extensive review conducted of the current research, to determine what might be applicable to nuclear powerplant operations.

The studies that were included in this review were those that emphasized the performance components most similar to the job of control-room operators. The results of this study were not conclusive regarding the best possible shift scheduling alternative.

In addition, research in other industries in past years has looked into circadian rhythm disruption, sleep disturbances, and the overall physical and psycho-social effects of shift work. Because of the substantial increase in shift work in the United States, the effect of shift work on health and performance should not be ignored.

The limited amount of so-called hard data from which to draw firm conclusions about shift work has made it incumbent upon NRC to attempt to establish a better technical basis on which to base additional guidance concerning shift work. This is consistent with the recommendation included in the comprehensive human factors long-range plans prepared for NRC by the Human Factors Society that shift duration and rotation be further evaluated.

To help in accomplishing this goal, the Division of Human Factors Safety has, as part of our safety technology program, initiated a modest effort on shift scheduling with the Human Affairs Research Center of the Pacific National Laboratories in January of this year.

The project's objective is to recommend guidelines to the NRC for evaluating shift scheduling plans and practices. Any recommended guideline will be based on a study of the relationship between the shift schedules, absenteeism, attrition, job satisfaction and, in turn, in effect the key, the effect of these factors on plant safety.

The project will include estimates of cost to the utilities of implementing the recommended shift schedule compared to alternative shift schedules. An extract of the statement of work for this contract is attached to my testimony for the record.

Studies on shift work, in general, show that workers feel negatively about the 8-hour rotating shift. NRC is aware of recent studies which indicate that the frequency and direction of the rotation makes a difference in physical and psychological effects.

There has been a move on the part of some other industries to try the 12-hour shift as a way of making shift work more desirable.

Thus far, the data on these 12-hour shifts are scarce and not very quantifiable.

The nuclear power industry now has two plants trying out the 12-hour shift. The obvious concern is operator performance, because of its impact on public health and safety.

The data obtained so far have been largely subjective, gleaned from personnel interviews and questionnaires administered to powerplant operators and shift personnel.

The responses did indicate a preference for the 12-hour shift over the 8-hour shift, and an analysis of the responses revealed that these preferences were generally for three reasons: (1) the 12-hour shift usually carried no additional overtime for the operators; (2) they—the operators—tended to believe they had more control over their time; and (3) the operators had more consecutive time off.

NRC is aware of one fossil electric generating plant that has conducted a 12-hour shift study, as did a small, one-plant electric cooperative. The results from the operators' view in both instances were favorable. In addition, a survey of nuclear powerplant operators at one plant has also resulted in 93 percent of the operators being in favor of a 12-hour shift schedule. However, the long-term results of these activities have not yet been determined.

NRC looks forward to the ongoing research in the area producing a better technical basis on which to issue additional guidelines that would be addressed toward enhancing safe nuclear operations.

As we stated, NRC's concern has to be with the operators' performance under stress—that is, the emergency conditions—and with the ability of the operators to maintain the plant in a safe condition. Given that the operators may prefer a longer shift for personal reasons, our concern still has to be with the effect their performance has on the plant.

The NRC is very interested in the concerns expressed here about the problems and effects of the biological rhythms and shift scheduling. We would be pleased to hear about any data that would be relevant to the activities that we have in regulating nuclear powerplants.

Thank you.

[The prepared statement of Mr. Thompson follows:]

# STATEMENT OF HUGH THOMPSON, DIRECTOR

DIVISION OF HUMAN FACTORS SAFETY

U.S. NUCLEAR REGULATORY COMMISSION

BEFORE THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

CONCERNING

BIOLOGICAL RHYTHMS AND SHIFT WORK SCHEDULING

MARCH 24, 1983

THE NUCLEAR REGULATORY COMMISSION IS PLEASED TO HAVE THE OPPORTUNITY TO PARTICIPATE IN THIS HEARING ADDRESSING THE PROBLEMS OF BIOLOGICAL RHYTHMS AND SHIFT WORK SCHEDULING. MY NAME IS HUGH THOMPSON. I AM THE DIRECTOR OF THE DIVISION OF HUMAN FACTORS SAFETY. WITH ME TODAY IS DR. DANIEL B. JONES, PROGRAM MANAGER FOR HUMAN FACTORS DEVELOPMENTAL PROGRAMS. THE NRC IS RESPONSIBLE FOR ENSURING PUBLIC HEALTH AND SAFETY IN NUCLEAR POWER PLANT OPERATIONS. THE DIVISION OF HUMAN FACTORS SAFETY IS RELATIVELY NEW TO THE NRC, HAVING BEEN IN EXISTENCE FOR APPROXIMATELY THREE YEARS. THE DIVISION ADDRESSES ALL THE HUMAN FACTORS SAFETY ISSUES RELATED TO NUCLEAR POWER PLANT OPERATION, INCLUDING CONTROL ROOM DESIGN, STAFFING, QUALIFICATIONS, TRAINING, AND SHIFT SCHEDULING.

NUCLEAR POWER PLANTS ROUTINELY OPERATE ON A TWENTY-FOUR-HOUR DAY, SEVEN-DAYS-A-WEEK BASIS. OPERATORS AND OTHER KEY PERSONNEL AT THOSE PLANTS MUST BE ON DUTY AT ALL TIMES. THUS, SHIFT WORK IS A WAY OF LIFE FOR THOSE PERSONNEL. THE NRC'S CONCERN IS WITH OPERATOR PERFORMANCE UNDER STRESS -- EMERGENCY CONDITIONS -- AND WITH THE OPERATORS' ABILITY TO MAINTAIN THE PLANT IN A SAFE CONDITION.

THE ISSUE OF SHIFT SCHEDULING AND OVERTIME AND THEIR RELATIONSHIP TO PLANT SAFETY GAINED PARTICULAR PROMINENCE AFTER THE ACCIDENT

AT THREE MILE ISLAND. WE HAVE APPROACHED THE PROBLEMS OF SHIFT WORK AND STAFFING FROM OUR REGULATORY POSTURE, WHILE CONCURRENTLY WORKING TO DEVELOP A FIRM TECHNICAL BASIS ON WHICH APPROPRIATE REGULATION CAN BE BASED.

NRC PRESENTLY HAS IN PLACE GENERIC LETTER 82-12, A COMMISSION POLICY STATEMENT, WHICH PROVIDES GUIDELINES FOR OVERTIME WORK FOR PLANT STAFF WHO PERFORM SAFETY-RELATED FUNCTIONS, E.G., SENIOR REACTOR OPERATORS, REACTOR OPERATORS, AUXILIARY OPERATORS, HEALTH PHYSICISTS, AND KEY MAINTENANCE PERSONNEL. IN UNUSUAL CIRCUMSTANCES, DEVIATIONS FROM THESE GUIDELINES MAY BE AUTHORIZED ON A TEMPORARY BASIS BY THE PLANT MANAGER OR HIS DEPUTY, OR BY HIGHER LEVELS OF MANAGEMENT. THIS DOCUMENT, HOWEVER, LAYS DOWN NO SPECIFIC GUIDELINES FOR THE ACTUAL SCHEDULING OF SHIFTS. IT DOES SPECIFY THAT (1) NO INDIVIDUAL SHOULD BE PERMITTED TO WORK MORE THAN 16 HOURS STRAIGHT, EXCLUDING SHIFT TURNOVER TIME; (2) NO INDIVIDUAL SHOULD BE PERMITTED TO WORK MORE THAN 16 HOURS IN ANY 24-HOUR PERIOD, NOR MORE THAN 24 HOURS IN ANY 48-HOUR PERIOD, NOR MORE THAN 72 HOURS IN ANY SEVEN DAY PERIOD (ALL EXCLUDING SHIFT TURNOVER TIME); (3) A BREAK OF AT LEAST EIGHT HOURS SHOULD BE ALLOWED BETWEEN WORK PERIODS (INCLUDING SHIFT TURNOVER TIME); AND (4) EXCEPT DURING EXTENDED SHUTDOWN PERIODS, THE USE OF OVERTIME SHOULD BE CONSIDERED ON AN INDIVIDUAL BASIS AND NOT FOR THE ENTIRE STAFF ON SHIFT.

THE NRC IS AWARE OF THE INHERENT PROBLEMS IN SHIFT WORK. IN 1980, WE HAD AN EXTENSIVE REVIEW CONDUCTED OF THE CURRENT RESEARCH TO DETERMINE WHAT MIGHT BE APPLICABLE TO NUCLEAR POWER

PLANT OPERATIONS. THE STUDIES THAT WERE INCLUDED IN THIS REVIEW WERE THOSE THAT EMPHASIZED PERFORMANCE COMPONENTS MOST SIMILAR TO THE JOB REQUIREMENTS OF CONTROL ROOM OPERATORS. THE RESULTS OF THIS STUDY WERE NOT CONCLUSIVE REGARDING THE BEST POSSIBLE SHIFT SCHEDULING ALTERNATIVE. IN ADDITION, RESEARCH IN OTHER INDUSTRIES IN PAST YEARS HAS LOOKED INTO CIRCADIAN RHYTHM DISRUPTION, SLEEP DISTURBANCES, AND THE OVERALL PHYSICAL AND PSYCHO-SOCIAL EFFECTS OF SHIFT WORK. BECAUSE OF THE SUBSTANTIAL INCREASE IN SHIFT WORK IN THE RECENT PAST, WE RECOGNIZE THAT THE EFFECTS OF SHIFT WORK ON HEALTH AND PERFORMANCE CANNOT BE IGNORED.

THE LIMITED AMOUNT OF SO-CALLED "HARD DATA" FROM WHICH TO DRAW FIRM CONCLUSIONS ABOUT SHIFT WORK HAS MADE IT INCUMBENT ON NRC TO ESTABLISH A BETTER TECHNICAL BASIS ON WHICH TO BASE DEFINITIVE GUIDELINES CONCERNING SHIFTS. TO ACCOMPLISH THIS GOAL, THE DIVISION OF HUMAN FACTORS SAFETY, AS PART OF ITS SAFETY TECHNOLOGY PROGRAM, HAS RECENTLY APPROVED A CONTRACT ON SHIFT SCHEDULING WITH THE HUMAN AFFAIRS RESEARCH CENTER OF THE PACIFIC NATIONAL LABORATORIES. THE PROJECT'S OBJECTIVE IS TO RECOMMEND GUIDELINES TO THE NRC FOR EVALUATING SHIFT SCHEDULING PLANS AND PRACTICES. THE RECOMMENDED GUIDELINES WILL BE BASED ON A STUDY OF THE RELATIONSHIP BETWEEN SHIFT SCHEDULING AND ABSENTEEISM, ATTRITION, JOB SATISFACTION AND, IN TURN, THE EFFECT OF ALL THESE FACTORS ON PLANT SAFETY. THE PROJECT WILL INCLUDE ESTIMATES OF COST TO THE UTILITIES OF IMPLEMENTING THE RECOMMENDED SHIFT SCHEDULE COMPARED TO IMPLEMENTING ALTERNATIVE

SHIFT SCHEDULES. AN EXTRACT OF THE STATEMENT OF WORK FOR THIS CONTRACT IS ATTACHED FOR THE RECORD.

STUDIES ON SHIFT WORK, IN GENERAL, SHOW THAT WORKERS FEEL NEGATIVELY ABOUT EIGHT-HOUR ROTATING SHIFT WORK. NRC IS ALSO AWARE OF RECENT STUDIES WHICH INDICATE THAT THE FREQUENCY AND DIRECTION OF THE ROTATION MAKES A DIFFERENCE IN PHYSICAL AND PSYCHOLOGICAL EFFECTS. THERE HAS BEEN A MOVE ON THE PART OF SOME OTHER INDUSTRIES TO TRY 12-HOUR SHIFTS AS A WAY OF MAKING SHIFT WORK MORE DESIRABLE. THUS FAR, THE DATA ON THESE 12-HOUR SHIFTS ARE SCARCE AND NOT VERY QUANTIFIABLE. THE NUCLEAR POWER INDUSTRY NOW HAS TWO PLANTS TRYING OUT THE 12-HOUR SHIFT. THE OBVIOUS CONCERN IS OPERATOR PERFORMANCE BECAUSE OF ITS IMPACT ON THE PUBLIC HEALTH AND SAFETY. THE DATA OBTAINED SO FAR HAVE BEEN LARGELY SUBJECTIVE, GLEANED FROM PERSONNEL INTERVIEWS AND QUESTIONNAIRES ADMINISTERED TO POWER PLANT OPERATORS AND OTHER SHIFT PERSONNEL. THE RESPONSES DID INDICATE A PREFERENCE FOR 12-HOUR SHIFTS OVER EIGHT-HOUR SHIFTS. ANALYSIS OF THE RESPONSES REVEALED THAT THE PREFERENCE FOR 12-HOUR SHIFTS WAS GENERALLY FOR THREE REASONS:

1. THE 12-HOUR SHIFT USUALLY CARRIES NO ADDITIONAL OVERTIME.

2. OPERATORS HAVE MORE CONTROL OVER THEIR TIME.

3. OPERATORS HAVE MORE CONSECUTIVE TIME OFF.

THE NRC IS AWARE OF ONE FOSSIL ELECTRIC GENERATING PLANT THAT CONDUCTED A PILOT STUDY OF 12-HOUR SHIFTS, AS DID A SMALL, ONE-PLANT ELECTRIC COOPERATIVE. THE RESULTS FROM THE OPERATORS' VIEW IN BOTH INSTANCES WERE FAVORABLE. IN ADDITION, A SURVEY OF NUCLEAR POWER PLANT OPERATORS AT ONE PLANT HAS ALSO RESULTED IN 93% OF OPERATORS BEING IN FAVOR OF THE 12-HOUR SHIFT SCHEDULE. THE LONG-TERM RESULTS ARE YET TO BE DETERMINED.

NRC LOOKS FORWARD TO THIS PROJECT PRODUCING A SOUND TECHNICAL BASIS ON WHICH TO ISSUE ADDITIONAL GUIDELINES THAT WILL ENHANCE SAFE NUCLEAR PLANT OPERATIONS.

AS WE HAVE STATED, THE NRC'S CONCERN HAS TO BE WITH OPERATOR PERFORMANCE UNDER STRESS -- EMERGENCY CONDITIONS -- AND WITH THE ABILITY OF THE OPERATORS TO MAINTAIN THE PLANT IN A SAFE CONDITION. GIVEN THAT THE OPERATOR MAY PREFER LONGER SHIFTS FOR PERSONAL REASONS, OUR CONCERN HAS TO BE THE EFFECT OF THOSE SHIFTS ON PLANT SAFETY.

THE NRC IS VERY INTERESTED IN THE CONCERNS EXPRESSED HERE ABOUT THE PROBLEMS AND EFFECTS OF BIOLOGICAL RHYTHMS AND SHIFT WORK SCHEDULING. WE WOULD BE PLEASED TO HEAR ABOUT ANY DATA OR RELEVANT INFORMATION THAT WOULD BE APPLICABLE TO OUR CONCERNS ABOUT THE EFFECTS OF SHIFT WORK.

## STATEMENT OF WORK

Project: 5-6 SHIFT SCHEDULING

Task Manager: D. Morisseau

Project Start Date: 1-1-83

Project Completion Date: 5-28-84

### Background

Characteristics of shift scheduling can include the number of crews, the number of shifts per day, the number of hours for each shift, fixed vs. rotating shifts, speed of rotation, forward vs. backward rotation, number of full weekends off per month, and whether a schedule keeps team composition fixed or in constant change. Shift scheduling can affect plant safety through its effect on overtime, absenteeism, attrition, team spirit, job satisfaction, and one's (off-the-job) social life.

Review of utility license applications requires an assessment of the adequacy of the number of shift crews. The Standard Review Plan (NUREG-0800, p. 13.1.2-7) states, "For on-shift persons, the total manpower available should be reviewed to assure that in excess of five full operating shift crews are planned so that excessive overtime is not routinely scheduled for these crews." In practice, most nuclear utilities are now using, or moving toward, six full shifts to provide time for requalification training without regular use of overtime.

### Objective

The objective of this project is to recommend to the NRC guidelines for evaluating shift scheduling plans and practices. This recommendation will be based primarily upon a study of the relationship between shift scheduling and overtime, and secondarily upon studies of (1) the relationship between shift scheduling and absenteeism, attrition, team spirit, job satisfaction, and social life; and (2) the effect of all these factors on plant safety. The project will include estimates of the cost to the utility (in salaries and overtime pay) of implementing the recommended shift schedule, compared to implementing alternative shift schedules.

Mr. REID. Thank you very much, Mr. Thompson.

Dr. Reighard, I have a number of questions I would like to ask you.

An Air Force study last summer concluded that research is needed "to design duty-rest cycles which least disrupt the sleep-wake cycle and minimize deterioration and alertness in performance."

Would you agree with this statement?

Dr. REIGHARD. Basically I would agree for the reason that anything that extends the body of knowledge relating to this phenomenon would be desirable.

Mr. REID. I noted some hesitation, however, in your answer. What was that?

Dr. REIGHARD. I didn't notice the same hesitation, but I will assume that it was there.

As I indicated, we have conducted studies for some 20 years. As the result of those studies relating to shift work, we have not found it necessary to intervene in the shift practices as they exist in the FAA today. As I indicated, those practices and the establishment of those practices and schedules are participated in by the controllers themselves.

Mr. REID. I appreciate that. Some of the earlier testimony that we had dealt with management and labor and looking at this difficult problem.

The FAA has been studying human biological rhythms since the 1960's. Why haven't the results of such studies been put to use in designing body rhythm compatible duty-rest and rotating shift schedules?

Dr. REIGHARD. I think my prior response is a partial response to this question as well. We have not seen fit to intervene with regard to the practices as they exist because the practices as they exist were the subject of our study, and we did not find anything that suggested they need to be change.

Mr. REID. Do you feel that the employees had enough knowledge to understand that it made any difference?

Dr. REIGHARD. In the sense that we could not discover any effect on productivity, efficiency, performance, whatever term you wish to use, and the work force demonstrated satisfaction with the circumstances.

There may have been exceptions, but for the most part they demonstrated satisfaction with these practices. We believe it was a contributing factor to allow them to make these choices, since we couldn't demonstrate any deleterious effects from the studies we have done.

Mr. REID. Doctor, were there other alternatives that you looked at, however?

Dr. REIGHARD. Yes. The studies done on duty, of course, dealt with the shift rotation practices in effect, but laboratory studies were done also, using different periods of work and wake-sleep.

Mr. REID. One of the things that we have learned is that all the experts that we have heard testify for the last two days agree that regardless of the length of the shift, that rotation by phase delay is much, much better than the phase advance rotation.

The pattern followed most at the air traffic control is phase advance and from the testimony that I have heard what is followed at the FAA is directly opposite to what the experts have said is best.

Dr. **Reighard**. Yes.

Mr. **Reid**. Is there any particular reason for that?

Dr. **Reighard**. It relates to the desires of the controllers and management acceding, to some extent, to their desires. The configuration referred to as 2-2-1 is the one that provides the longest period of time off duty at the end of the work week.

Since, as you know, there are laws that prescribe the work hours per day and the work hours per week, which are respectively eight and 40, in order to get the 40 hours work in, at least eight hours rest time, and work no more than eight hours per day, this kind of schedule is mathematically the one that provides that set of circumstances.

Mr. **Reid**. The problem I have with that, Doctor, is it seems to me that when we are dealing with something as important as the safety of the flying public, the leisure time of the air traffic controller should be a secondary consideration. All the testimony we heard earlier indicates that alertness and vigilance certainly is much less of a problem using a phase delay program.

Dr. **Rieghard**. Mr. Chairman, we are very much interested in the safety of the traveling public. That is our basic mission. We have not found any safety implications attaching to the shift rotation practices among the controller work force.

Mr. **Reid**. Do you think the controllers would object to reversing the current rotation sequence, especially if they knew from a scientific standpoint that it would be easier to adjust their sleep-wake cycles under a new regime?

Dr. **Rieghard**. You asked if I think they would be accepting. I will respond with my opinion. I believe one must assume, and we have demonstrated that controllers are very intelligent, capable, mature individuals. Attributing those attributes, I would think they would have to have demonstrated to them in some very concrete ways the wisdom of doing this apart from laboratory studies and assertions with regard to predicted effects.

If they have not actually seen the effects, either on their performance or their health or what have you, I think they might be unaccepting of a change to some other pattern.

Mr. **Reid**. We have seen some studies that show that truck drivers and train operators showed temporary sleep patterns in EEG records while the vehicles were being operated and the operators didn't realize it. In effect they were dozing during their work periods, even though they didn't realize it.

The only concern I have in your response is that if we have laboratory information that suggests there may be a problem with sleepiness or reduced alertness on the jobs as a result of poor shift schedule, I would think that the FAA would be very interested in this. That is one of the reasons we are conducting these hearings.

Dr. **Reighard**. Yes, sir.

Mr. **Reid**. Do you know, Doctor, whether or not the agency has compared the rapid and the 5-day rotation schedules with 3-week or longer schedules?

One of the things we have heard the last couple of days is that the longer a person is on a particular shift before the change takes place, the better off they are.

Dr. **Reighard**. I would like to defer to Dr. Melton to respond, since he has been involved in most of the studies in this area.

Mr. **Reid**. Dr. Melton, would you, for the record, give us your name and tell us your position.

Dr. **Melton**. My name is Carlton E. Melton. I work at the Civil Air Medical Institute of the FAA in Oklahoma City, where I am Supervisor of the Aviation Physiology Laboratory.

Mr. **Reid**. We welcome you here. Please proceed.

Dr. **Melton**. Yes, sir, we have carried out comparisons of other shift patterns; one other shift pattern, I should say. It is the so-called steady shift, which is worked at the Miami International Flight Service Station.

They are an innovative program of worker participation and shift selection. They offered their workers an opportunity to bid on shift patterns that they might prefer to work. The two patterns there were the 2-2-1 and the steady shift.

I should point out at this time that we only completed the data collection phase of the study at Miami in December, and we are still in the data analysis phase of it, so we have no firm conclusions from that study as yet. The biochemical analyses take a considerable length of time.

Mr. **Reid**. Doctor, in these studies did you do anything to measure brain waves?

Dr. **Melton**. No, sir, we did no electroencephalographic work.

Mr. **Reid**. The information that we have gathered, indicates that this is probably one of the few ways that you can test alertness and vigilance. You would agree to that, would you not?

Dr. **Melton**. Yes, sir, very clearly.

Mr. **Reid**. One other question I would ask, based upon your previous answer. Did the people that participated in this study have any information available to them or was there any information that could have been given to them from your standpoint that could have told them about these circadian rhythms and about the different problems that could arise on different shift schedules?

Dr. **Melton**. Mr. Chairman, I can't answer that question of my own certain knowledge. I do know that these people have a very practical working knowledge of circadian effects.

Mr. **Reid**. I am wondering if you could supply to the committee whatever background these people may have had, and it may just be their experience in the work field. Would you give that to us so we would have that to complete this record?

Dr. **Melton**. In my discussions with them at the Flight Service Station, they exhibited a great deal of interest in circadian effects. I discussed some of the scientific aspects of circadian rhythmicity with the work force there. They indicated to me that they had a pretty good knowledge of this.

I should say that there was a heavy overlay of let's say astrology and other such popular devices involved. There was a deep interest, but I would have to say only a practical and working operational knowledge of circadian effects, that they knew from their own responses what happened to them as far as sleep and social interests and things of that sort were concerned as associated with the various shifts that they worked.

Mr. REID. As I understand your answer, the information available to these people depended upon the experience they had gained in their work and leisure time activities. You mentioned astrology, for example. Some people may base more on the stars than others, so to speak.

Dr. MELTON. Yes, sir.

Mr. REID. Did you want to add anything, Doctor, to that answer?

Dr. REIGHARD. I would like to respond with regard to the questioning concerning the electroencephalograms. I would like, in reference to reduced levels of alertness, to point out that except for a small number of facilities where there may be just one person on duty, such as a small tower, evening shift, what have you, there are multiple persons present to observe the state of an individual who is expected to be controlling traffic such that although Dr. Melton's response was that the electroencephalogram was about the only certain measure of level of alertness, I would like to point out that observers are also in a position to determine if an individual is responding to stimuli and doing his job.

Mr. REID. As I understand your survey, the data were obtained from forms filled out by air traffic controllers. I don't believe they had anybody observing them, and recording their performance, did they?

Dr. REIGHARD. The studies done over the past 20 years have taken a variety of forms.

Mr. REID. I thought we were talking about the one involving the different work schedules. You say that was based upon a number of studies over a long period of time.

Dr. REIGHARD. They took different forms, and some of the forms were questionnaire. They may have been supplementary to actual scientist or technician observation as well.

Mr. REID. Doctor, it is my understanding that none of them, at least from the information that we have received, involved brain wave testing. Is that correct?

Dr. REIGHARD. That is correct.

Mr. REID. I would now like to ask some questions of you, Mr. Thompson.

Mr. THOMPSON. Please do.

Mr. REID. There will be other questions asked of you, Doctor Reighard, by some of the staff, when I finish with Mr. Thompson.

I would only like to say I appreciate very much and I think it is refreshing to find an agency such as the NRC that, in effect, recognizes the need to pay attention to the effects of shift work on health and performance. We commend you for that, Mr. Thompson.

Mr. Thompson, you indicated in your testimony this morning that the Human Factors Division has been in existence I think you said 3 years.

Mr. THOMPSON. Correct, about three years.

Mr. REID. I think you also said that the Three Mile Island incident was one of the contributing factors to development of this division

Mr. THOMPSON. Before its creation, that is correct, yes, sir.

Mr. **Reid**. Prior to the Three Mile Island problem, had there been any interest by the NRC in circadian rhythm studies?

Mr. **Thompson**. Not that I am aware.

Mr. **Reid**. Tell us again why you think the Three Mile Island incident brought this to the attention of the agency.

Mr. **Thompson**. The circadian rhythm aspect probably was not brought to the attention of the Commission by the Three Mile Island incident itself. What happened after Three Mile Island was that we had a number of investigations and studies looking at all the primary and secondary effects.

The primary effect tended to focus on the control room, the adequacy of the operator's training, the information that was provided to the operators in the control room and their knowledge of what that information would allow them to do.

A spinoff was into areas such as maintenance, the maintenance of the valves and what contributed to those aspects.

As we put the entire human factors program plan together, it turned out that one of the areas that we became aware of was that a number of operators had complaints about extensive amounts of overtime, long work hours, and the difficulties that this created for them.

Because of this, it turned out to be more of an awareness of the problems of the industry and the difficulties that the operators were having in general rather than the Three Mile Island incident itself; that is, TMI heightened our sensitivity to the issues that were existing in the normal work force that were due to the 7-day, 24 hours a day work week.

Mr. **Reid**. I also understand that absenteeism, attrition, things of that nature, of course, would bring your attention to it, would they not?

Mr. **Thompson**. It does to the extent that it impacts the need for overtime; that is, when utilities have difficulty in staffing, getting qualified people, they end up having to have additional operators come on board. The dissatisfaction with the job results in a high turnover rate in the industry, operators leaving shift work, and having higher absenteeism.

We haven't necessarily in the past kept records on absenteeism or job satisfaction. This is one of the areas that we are looking at as part of the activities we are concerned with; that is, whether or not we, as a regulatory agency, should issue guidance for the industry in this area.

Mr. **Reid**. This is one of the things that you will be looking into with this newly commissioned shift work project?

Mr. **Thompson**. Correct.

Mr. **Reid**. From the work statement it appears that no biological factors are to be studied, or if they are, I didn't see it in the information provided. Are they to be studied?

Mr. **Thompson**. You mean actual studying? It is more of a literature survey as opposed to actual research type measurements.

Mr. **Reid**. That is my understanding, the gathering of information.

Mr. **Thompson**. That is correct.

Mr. **Reid**. As far as you know, will that be the extent of your study at this time?

Mr. THOMPSON. Yes, at this time. Obviously, as we proceed we may identify a need to expand, to collect other data if necessary, to actually identify the quantifiable improvements in safety.

I think that this is the same problem the FAA has indicated from a regulatory viewpoint, that is, being able to identify this in a quantifiable way so that you can directly relate a need for a regulatory body to specify in a prescriptive manner what the industry's practice should be with respect to shift work and scheduling.

It is important that we be able to do that to justify our regulations.

Mr. REID. Of course—and I am sure nothing like this ever happened—I am sure if you saw somebody dozing off, you could quantify that.

Mr. THOMPSON. That is correct. We do have what we call resident inspectors who are there at the utility. They have a certain portion of their time spent on the back shifts to observe the alertness of operators, and the need for them to be there.

In addition, we are requiring as a regulatory aspect the addition of a senior supervisor to be in the control room at all times.

Mr. REID. As far as you know, are there any reports filled out by these people?

Mr. THOMPSON. With respect to reporting incidents—I think you are probably referring to licensee event reports. There are two types of reports that are reported now. One of them is the LER—License Event Report—system.

We are in the process—because of the inadequacy of that reporting system—to identify, specifically in fact, sometimes the time-related aspects, as to when the event occurred, sometimes when it was discovered as opposed to when it occurred, and its relationship to the human factors. Because of that, we are now revising that reporting system in order to provide a better basis for the information that we would have concerning the impact of fatigue or shift-work scheduling on operators.

Second, the industry itself has, through the INPO—the institute for nuclear Powerplant operations—in Atlanta, Ga., a trial or pilot program which interviews operators after each event at that plant, with a professional human factors individual talking to the individuals to find out specifically what were the contributors to that effect, whether it was training, scheduling, tiredness. The results from this effort will be looked at and determined whether they wish to expand that on a nationwide program.

Right now those are the two methods. One is an industry-volunteered reporting system and another one is one in which they are required to report those significant events to us.

Mr. REID. Has the NRC ever commissioned a study of vigilance and alertness as a function of shift time? We haven't been able to find anything that the NRC has done in conducting any studies as to alertness and vigilance as it relates to shift time.

Mr. THOMPSON. I am not aware of any study.

Mr. REID. Do you know whether or not there is anything like this contemplated?

Mr. THOMPSON. I will ask Dr. Jones, if he would respond.

Mr. REID. Dr. Jones, we will need your full name for the record and your position.

Dr. **Jones**. It is Dr. Daniel B. Jones. I am the project manager for developmental human factors programs for the NRC.

At this point in time we have not contemplated measurement techniques to look at vigilance. There has been a considerable body of work conducted by the military, and other industries. We believe that the data that are available from there will be useful to us.

If, in the course of our current review of the literature and development of information, we find that we do have to develop our own data, we will do so. This will be handled by the Research Department of the Nuclear Regulatory Commission.

Mr. **Reid**. Thank you, Dr. Jones.

I am going to turn the Chair back to Mr. Gore, but prior to doing so I would like publicly to state that I have been very impressed by this testimony. You gentlemen haven't been available the last couple of days, but we have gone through a large battery of witnesses.

Chairman Gore, I commend you for your work in getting this study together. I am confident that when the staff puts all this together, that it will be a landmark study of the problems of shift work. I think a lot of well-meaning people simply don't have the information at hand to make judgments as to the negative effects of shift work.

I can't tell Chairman Gore how much I commend him for getting into this area. It is not like listening to a committee hearing on the budget, but the subject is clearly important for hundreds of thousands of people who work rotating shifts. When this study is completed, it will allow both the employer and labor to make reasonable judgments about shift scheduling based upon scientific evidence.

Chairman Gore, I am sorry that I am going to have to be excused.

Mr. **Gore** (presiding). Thank you very much for those kind words and for your contribution to these hearings.

I have a couple of questions, but I would like to recognize counsel for the minority.

Mr. **Rheem**. Thank you, Mr. Chairman.

Mr. Skeen raised a couple of questions yesterday that I wanted to follow up on, Dr. Rieghard, the results of your research bring up a couple of problems.

First of all, it doesn't seem to match the accumulation of research coming out of the field, especially some of the more recent research.

Second, it has come out in your testimony, and especially in what Mr. Melton said, that your research would not even identify some of the most important safety-related aspects of shift work, lack of alertness, and so forth, because you are not measuring for those things.

With those two thoughts in mind—one, that your research seems to be at odds with what is coming out of the field and second, that your research also doesn't seem to be at the level of sophistication that might identify some of the most serious problems—at what threshold of accumulated research in the field would we expect the FAA to perhaps take another, more detailed look at this problem?

Dr. REIGHARD. I think it is important to draw a distinction between physiological measurement of change and the relevance of those changes that can be demonstrated to the occupation of concern.

I would say that Dr. Melton and his associates have made demonstrations and have advanced the state of the art with regard to physiological measurement in a pretty sophisticated way over the years.

They have demonstrated the effects that result from altering the time schedule of individuals, both on work and in laboratory situations. They have manipulated individuals and their sleep-wake cycles and made physiological, biochemical, and performance measurements.

What we have concluded, after having done this, and also having reviewed the literature—and I dare say our scientists are as conversant with the literature as is appropriate to the determinations that we have to make—we must conclude that it has not been demonstrated that it has relevance to the actual performance, efficiency and effectiveness in air traffic control.

Mr. GORE. Would counsel yield?

Mr. RHEEM. Certainly. I would be happy to.

Mr. GORE. How did you measure vigilance in these studies?

Dr. REIGHARD. I will defer to Dr. Melton.

Dr. MELTON. I think I would have to respond, Mr. Chairman, by saying that the air traffic people who are responsible for monitoring the performance of the workers in the workplace never themselves detected any derogation of vigilance.

Mr. GORE. That is not the question. Dr. Reighard just said that you had very sophisticated, scientific tests in the laboratory, as well as in the field, measuring the effects of different shift rotation patterns.

I am wondering, how did those tests measure vigilance?

Dr. MELTON. In the laboratory we have a very sophisticated battery of tests—we call it the multiple task performance battery—consisting of, I believe, 14 different, separate tasks involving meter reading, tracking, response time, mental arithmetic, light cancellation tasks, all of which are presented in sequence and in combination. The results of this are scored automatically by computer.

Mr. GORE. Do you have anything that measures alertness levels at low load?

Dr. MELTON. I assume you are referring to an electroencephalogram.

Mr. GORE. An EEG, brain waves, eye blinks, those things which traditionally are used to measure alertness levels.

Dr. MELTON. We have measured eye blinks. We have measured the electro-oculogram. We did not find it to be a particularly reliable or valuable measurement, so we dropped it in some of our later studies.

We have not measured the electroencephalogram on any of our field or laboratory studies.

Mr. GORE. Why not?

Dr. MELTON. In the field studies, we operate under a number of constraints. We are a little like an observer at a football game. We can see what is going on, but we can't in any way interfere with what is going on. This is particularly critical in air traffic control. Whatever we do must not interfere with the ongoing activity.

Also, because controllers shift positions, we operate under a constraint that whatever we do must not tie them to the one position at which they are operating. For that reason, we cannot, as we say in our business, pigtail to an electroencephalograph with a long wire. We can not telemeter this because we don't have the capability of doing that.

Mr. GORE. Do you have something that makes you believe that air traffic controllers or pilots have different kinds of body clocks than other people? Isn't it reasonable to assume that all people have the same sorts of body clocks?

Dr. MELTON. I think it is safe to assume that all people have this body clock. We see no difference in air traffic controllers.

Mr. GORE. Isn't it also reasonable to assume that the scientific studies that measure the impact of circadian desynchronosis or poorly designed shift rotation schedules on human beings are applicable to air traffic controllers and pilots?

Dr. MELTON. I would have to assume they are applicable there. Whether they are preferable or not, I can't really say. I think the important factor in shift patterns worked by air traffic controllers is what they wish to work. There are factors entering into that that haven't been touched on here.

Mr. GORE. Would you say that their personal preference would be the overriding consideration if scientific evidence indicated that the public was at risk because of poorly designed shift rotation schedules?

Dr. MELTON. I can assure you that if the FAA believed the public was at risk in any regard, they would take immediate steps. We have no such indication. We have no indication that there is any effect on their health.

Mr. GORE. Counsel's question—and I appreciate his indulgence—really gets to the point that your conclusions seem to be directly at odds with the consensus opinion outside of the FAA. That seems curious. You haven't done the brain wave studies, and that ought to diminish the extent to which you would rely on your own conclusions.

Given the fact that the rest of the scientific community disagrees with you, and given the fact that your studies have not included this key test for alertness levels, your conclusion might be that you are wrong.

Dr. REIGHARD. Mr. Chairman, I would like to respond to that.

I believe I indicated that our orientation with regard to the measurable physiological and biochemical performance changes that occur as a result of disruption of the timeclock in the human being is well known to us, and we share in that information, so that we do not disagree with the prevailing body of scientific information in this subject area at all.

It is true I was not here for the testimony yesterday or, for the most part, this morning. I can only perceive what the boundaries of disagreement might be. It would seem to be that it has to do with the applicability to a particular kind of work effort; in our case, air traffic control.

We have said we have seen no effect on safety by the practices as they exist in the FAA. We have demonstrated no significant effect on performance as required by air traffic controllers in controlling traffic.

Mr. **Gore**. You weren't here yesterday and as you said, quite appropriately, you weren't familiar with what was said yesterday or this morning before you got here. Let me just summarize briefly what was said.

There have been a number of breakthroughs in this research within the last few years. This sub-specialty is still in its infancy, and a great deal of research still needs to be done. But there is now a virtual unanimity on the fact that you ought to rotate shifts forward slowly and that you ought to allow enough time between rotations to allow people to adjust. There are scientific studies that show the detrimental effect on people who don't have the opportunity to adjust, and who are rotated in the wrong fashion.

You have jurisdiction over a critical profession. We had testimony yesterday, incidentally, that a number of fatal air crashes may well have been directly related to this phenomena. I will refer your attention to the record of yesterday's hearing.

We had testimony about a plane going from Chicago to Los Angeles and flying 100 miles past Los Angeles, right out over the ocean. That was attributable to one of the phenomena that researchers in this field discovered, which is a waking nap, I guess you would call it, almost a trance state where people's eyes are open but the brain wave activity diminishes to a point that resembles sleep, even though their eyes are technically open. This has been found to occur on freeways as well.

Enter the FAA. Here is what the FAA has done, and you correct me if I am wrong. You have studied two shift-rotation patterns. You have studied the physiological effects on air traffic controllers who were in two different shift-rotation patterns. Is that correct?

Dr. **Melton**. Yes.

Mr. **Gore**. What if I told you that both of the shift rotation patterns that you studied were terrible from a scientific point of view? If that were the case, then the differences in the physiological evidence collected from one group compared to the other would not be particularly significant.

One of your shifts is a one change every 1 or 2 weeks in the wrong direction and the other is a change far too quickly, the 2-2-1, to allow adjustment, and it is also in the wrong direction.

If your study is to take people who are in two different shift rotation patterns and compare the effects of those shift rotation patterns, one against the other, and if both of them are wrong, then you are not going to find out what you need to know.

If you compare that effort with this relatively new but impressively accumulating body of knowledge that is coming out of the laboratories and out of experiments like the Great Salt Lake experiment, it just really seems to me that the FAA ought to rethink its approach to this because the public may very well be at risk.

Dr. **Reighard**. I am not sure, in the interest of time, which of the assertions I should respond to. In the laboratory we did study patterns other than the operational patterns that now exist. I can recall one study in the laboratory in which individuals were put on a 12-hour sleep-wake cycle. There were certain other sleep deprivation types of studies to add to our understanding of the phenomenon of dislocation of time cycles and individuals.

I indicated that our scientists are conversant with the literature, including the present literature. One term you used was "detrimental." It would be my impression from what has been said and the nature of the questioning that the goal would be to maintain what I would refer to as a homeostatic status; namely, keep everyone in the best possible physiological shape.

That manipulation may not have any relevance for performance or productivity at all. We heard of the 25-hour cycle, to which we are all subjected. Have any of us altered our practices and established a 25-hour day? It seems patently inappropriate to consider that kind of reasoning.

Mr. GORE. Let me back up. Again, you weren't here yesterday. The way it works I am told by the scientists who testified is not that we have a 25-hour body clock that constantly throws us out of sync with the 24-hour day. We reset our body clocks each day.

If you have an experiment where people can't see the Sun or any clocks and they have nothing by which to reset their clocks, then the normal drift is toward a 25-hour cycle. But in everyday life, people reset their body clocks every 24 hours, or they are constantly resetting toward a 24-hour cycle, but the normal drift, the normal tendency is toward a 25-hour cycle.

Your comments just lead me to ask this question. Are you familiar with the research that has been coming out, Dr. Czeisler's work or Dr. Moore-Ede's work, for example?

Dr. REIGHARD. I would like to make it clear that I am not a researcher. When I refer to familiarity with the results of recent research, I refer to our scientists at the Civil Aeromedical Institute.

Mr. GORE. I see.

Dr. REIGHARD. I believe they are familiar with this work. I would like to respond to——

Mr. GORE. Dr. Melton, are you a researcher in this area?

Dr. MELTON. Yes, sir.

Mr. GORE. Are you familiar with Dr. Czeisler's work or Dr. Moore-Ede's work?

Dr. MELTON. Yes, I am.

Mr. GORE. Are you familiar with the daily resetting of body clocks?

Dr. MELTON. I am, yes, sir.

Mr. GORE. Do you agree with Dr. Reighard's statement that he made a moment ago, that there is no evidence to support a contention that the scrambling of body clocks is detrimental to productivity or performance?

I may be doing damage to your statement in rephrasing it, but the implication I got from your statement was that, that there is no evidence to support a contention that productivity and performance can suffer from a poorly designed shift rotation schedule.

Dr. REIGHARD. What I precisely said was that we have demonstrated no detrimental effect on the performance as measured by productivity, effectiveness, health status, and certain other factors with regard to the shift rotation patterns practiced by the FAA.

I did not make a statement concerning the general phenomenon of desynchronosis.

Mr. Gore. Wait a second. You said you have determined no detrimental effect of your shift rotation patterns. Compared to what?

Dr. Reighard. I am not quite sure I understand the statement.

Mr. Gore. I am not quite sure you do, either. The fact is you said there is no detrimental effect. You have to have a baseline to compare that against. You say there is no detrimental effect of the shift rotation pattern that is in use. No detrimental effect as compared to what?

Dr. Reighard. One concrete observation I can make is that of the three basic shift periods—a day shift, an evening shift, and a midnight to early morning shift—the midnight to early morning shift is that which would produce the greatest desynchronization.

The measures of effectiveness of the performance in air traffic control are called systems errors, incidents in which the prescribed standard separation of aircraft becomes less than is considered appropriate for that particular operation.

Seven percent of aircraft operations are handled by the air traffic control system in the period between midnight and 8 o'clock in the morning. Only 5 percent of the systems errors occur during that period which is, as I have indicated, the period of most serious disruption of the wake-sleep and the body clock mechanisms.

Mr. Gore. The number of errors shouldn't necessarily have a linear relationship to the volume of traffic. When you have only one plane coming in every 90 minutes, you are a lot less likely to make mistakes than you are when you have a whole bunch of planes crowding the sky at the same time.

I would not take much comfort from a linear relationship between incidents of errors and volume of traffic. If you have only 7 percent of the traffic during that time of the day, then you ought to have far fewer than 5 percent of the errors. Doesn't that make sense?

Dr. Reighard. I take as inferential in your observation that you would assume the same level of work force operates between 12 o'clock and 8 o'clock, and that is not true. The work force is sized according to the workload.

I do not assert that the numbers of planes handled in a given unit of time during the midnight to 8 o'clock shift is at all times the same as that of the day shift. However, I would call to your attention that aviation activity, at least at the busier locations, the metropolitan areas, comes alive somewhat before 8 o'clock in the morning.

Mr. Gore. I am looking at your own studies. They seem to indicate that for people on the 2-2-1 shift rotation system, the people who are working the midnight shift are getting an average of 3½ hours sleep per 24 hours. That is according to your own study.

Dr. Melton. Yes, sir; bear in mind that on that rotation pattern they only work one midshift, which is the last day of the workweek. The practice commonly is that they will take a nap prior to going on duty at midnight, work that midshift, go off duty at 8 the next morning and then have effectively 4 days off duty following that one midshift.

Mr. **Gore**. But they get progressively less sleep with each shift change. They get 7½ hours sleep on the evening shift, according to your study, 5.8 hours on the day shift, and then 3½ hours on the midnight shift.

Dr. **Melton**. The one midnight shift.

Mr. **Gore**. Yes.

Dr. **Melton**. This is about in line with and maybe somewhat more than industrial workers as a whole, who sleep about 6½ hours.

Dr. **Reighard**. Mr. Chairman, could I consult with Dr. Melton for just 1 minute?

Mr. **Gore**. Sure.

Dr. **Melton**. Mr. Chairman, Dr. Reighard has just clarified my thinking on this as to what the confusion is.

This pattern, 2-2-1, if I may run it down specifically, might go something like this, if it were a Monday through Friday sequence.

The controller would go to work at 4 o'clock on Monday afternoon and work until midnight. The next day he would go to work at 2 o'clock and work until 10 at night. The third day he would go to work at 8 in the morning and work until 4 in the afternoon. The fourth day he would go to work at variously 6 or 7 in the morning and work until 2 or 3 in the afternoon. So that ending the fourth day of work in early or midafternoon and going to work again at midnight on Friday morning, he would have 9 or 10 hours off duty, depending on the specific pattern that he has.

He has an opportunity for sleep, if he chooses to use it that way. As I indicated, the practice is that they will take a nap before that shift, work the shift and go off duty for an extended period of time. There is no accumulation of fatigue.

Mr. **Gore**. He may have an opportunity, but his body clock may be on a schedule that prevents him from taking advantage of that opportunity. It may be on a schedule that prevents him from getting decent quality sleep even if he can get to sleep.

These, after all, are people who have a very high rate of burnout, do they not?

Dr. **Melton**. No, sir.

Mr. **Gore**. Is there a problem with early retirements and health complaints with air traffic controllers?

Dr. **Melton**. Would you like to speak to that?

Dr. **Reighard**. I would like to respond to the early retirement observation and on my own make the observation that over time, at least before August 3, 1981, there was an accelerated rate of retirement for disability. The reasons for that involve almost a social phenomenon, which I won't go into unless the committee wishes. It cannot be, however, used as a measure to indicate the level of demand, stress or burnout attributed to air traffic controllers.

I will call attention to just one study, and that was the Boston University study done by Dr. Robert Rose. It took a period of 5 years and to our satisfaction that study demonstrated, as many other studies have done, many other less comprehensive studies have done, that controlling air traffic is not a uniquely stressful occupation.

Further, the Rose study, entitled "The Air Traffic Controller Health Change Study," did not find, except for over-representation of elevated blood pressure, any significantly different health change in this occupation than in other occupations or the general population.

Mr. **Gore**. What on-duty complaints are most frequently cited by air traffic controllers? Fatigue, weakness and sleepiness?

Dr. **Reighard**. I don't know that we have——

Mr. **Gore**. Dr. Melton, isn't it fatigue, weakness and sleepiness? These are your data.

Dr. **Melton**. Those are common complaints.

Mr. **Gore**. In your data those are the most common complaints. On which shift are most of these reported?

Dr. **Melton**. The midshift.

Mr. **Gore**. The midnight shift. Ninety-five percent of the complaints on the rattler schedule, the 2-2-1, are sleepiness and fatigue. Isn't that correct?

Dr. **Melton**. Yes, sir.

Mr. **Gore**. Does that concern you?

Dr. **Melton**. No, sir, it is well within their reserve capacity to shoulder this load and do that work under those circumstances.

Mr. **Gore**. I find this testimony frustrating. In the Rose study, which you just cited, the two greatest complaints were digestive problems and sleepiness on shift work. Isn't that correct?

Dr. **Melton**. I believe that is correct.

Mr. **Gore**. The digestive problems that they cited in the Rose study are the kind that the scientists now tell us result from scrambling up body clocks. Does that surprise you?

Dr. **Melton**. I am aware of Dr. Rose's conclusions.

Mr. **Gore**. Are you aware of the connection between the scrambling of body clocks and digestive problems?

Dr. **Melton**. Mr. Chairman, I haven't seen any conclusive persuasive evidence that this is an inevitable result.

Mr. **Gore**. In other words, you challenge the link between digestive problems and circadian desynchronosis?

Dr. **Melton**. Let's say I am uncertain about the relationship in my own mind.

Mr. **Gore**. I see. Every major study that has looked at it comes up with this.

Dr. **Melton**. I am not aware of those.

Mr. **Gore**. Then how can you make these sweeping statements in your testimony that:

> * * * nor is there any medical evidence that is persuasive concerning the desirability of one shift pattern over another. Neither have we seen any indications of diminished work performance based upon the kinds of shifts worked.

I don't want to beat a dead horse, but here is the situation. The scientific evidence has become available. There is not much dispute about it. The field is in its infancy, but even in its early stage the conclusions which can be drawn about the preference of one kind of shift rotation schedule over another are indisputable.

Yet, the FAA, which has jurisdiction over the shift rotation schedules of this critical profession, air traffic controllers, as well as pilots, is oblivious to the scientific discoveries that have been made. Yet, you come into this hearing and say with some authority that there is no such evidence. I find that frustrating.

Again, I don't want to beat a dead horse, but let me tell you what I would like to happen. What I would like to happen is for the FAA to take another look at the evidence, to take a close look and report back to the subcommittee that after reviewing the evidence you have decided that yes, there is some reason to believe that some shift rotation patterns are better than others and because the public safety is involved, we are going to take some steps in this direction.

That is what I would like to happen. I realize it puts you on the spot to say, "Yes, Mr. Chairman, we will do that." I understand that, but I hope that after the hearing you will find the opportunity to do that. We will pursue it with you and have some other discussion about it and I will give you a chance to comment.

Dr. **Reighard**. We will be pleased to talk at any time with you or members of your staff. I would like to respond to one other observation in the rather compound question you put to me earlier.

I believe you indicated that you had testimony yesterday that there have been numerous accidents that have been attributed to fatigue.

Mr. **Gore**. Fatigue that might be related to circadian desynchronosis. That is in the record of yesterday's hearing.

Dr. **Reighard**. I would be most interested in looking at that, but I would like to make this statement in response to this observation.

Mr. **Gore**. Those are NTSB reports that were cited.

Dr. **Reighard**. There have been no accidents in part 121 operations—that is the air carriers—in which NTSB has cited fatigue as a factor and where the fatigue was clearly caused by the failure to provide an opportunity for rest.

Mr. **Gore**. I will come back to that.

Mr. Thompson, what have previous reports concluded regarding 12-hour shifts as opposed to 8-hour shifts.

Mr. **Thompson**. I would like to let Dr. Jones, who is the senior technical adviser in this area, respond to that.

Dr. **Jones**. The data seem to indicate that there is a decrease in vigilance over an 8-hour period. If you look at an 8-hour period, you will find an increasing lack of attention up to about 8 hours, and then beyond 8 hours that lack of vigilance maintains essentially the same level; in other words, from zero to 4 the vigilance gradually gets a little less, from 4 to 8 it stays about the same, but from 8 to 12 it is essentially the same, also.

Mr. **Gore**. How about 16-hour shifts?

Dr. **Jones**. I am not aware of any particular detailed work that has been done on that. I do know that the military have looked into this.

Beyond 12 hours there seems to be a small degradation in performance, depending on the kind of work. If it is the sort of thing that alerts the individual and brings his attention back up, such as an incident or accident, his whole bodily function takes over and he gets very much involved in the situation.

Mr. **Gore**. The NRC currently allows 16-hour shifts, right?

Dr. **Jones**. Yes, sir, under certain circumstances.

Mr. **Thompson**. I think this may be a misstatement. We allow an individual to work 1 day 16 hours as opposed to a 16-hour shift. We do not allow a 16-hour shift in the context of normal shift work.

Mr. GORE. Fine. I was out of the room earlier, so this may have been covered. It is my understanding that the possibility that the Three Mile Island incident may have been related to the shift rotation schedule and its effect on the operators on duty at 4 a.m. was in large part responsible for the NRC's effort in this area. Is that correct?

Mr. THOMPSON. I think I would characterize that slightly differently. I would say that the accident at Three Mile Island sensitized the NRC to the lack of attention that human factors has been given in all areas and that our efforts to become more aware of the human factors aspects with respect to the control room review and the training of operators and the examination aspects of this led us to become more aware of the problems that operators were facing with the fatigue and extra overtime. Because of the additional awareness, we are now evaluating the current literature and what is available with respect to the shift scheduling issue.

Mr. GORE. Let me come back, Dr. Reighard, to your concluding statement that the NTSB has never cited these factors as being key in an aircraft accident.

Here is the flight incident report from the NTSB for the Delta Airlines DC-8 that went down in Kenner, La. back in 1967: "The disturbed work-rest cycle superimposed on the natural stresses of the training environment was undoubtedly reflected in the performance of the captain-trainee." In the conclusions they say, "The captain-trainee's performance was affected by some degree of fatigue."

The incident report from NTSB concerning the Air New England-deHaviland flight that went down in Hyannis in 1979: "It is believed that the degraded physiological condition of the captain seriously impaired his performance." He had just worked a 14-hour shift and went back out again.

> Although the board was unable to determine conclusively the reason for the failure to recognize and react to the gross deviation, it is believed the degraded physiological condition of the captain seriously impaired his performance. The crew had worked a 14-hour duty day involving nine hours and 15 minutes of flight time.

We will review for you the other incident reports. The Airline Pilots Association submitted a statement yesterday which cited six incidents.

The study by NASA addresses the question, "What, if any, are the pertinent issues to the aeronautical community related to circadian desynchronosis?" NASA says:

> The use of the terms pilot fatigue or fatigue were troublesome to many, particularly to those from the biomedical research community. The participants became more comfortable with the concept of 'performance decrement of pilots.'

They go on to say, "Question 1: Is there an issue related to circadian desynchronosis?" Question 1 answered in the affirmative, that there is a problem, that there are issues here which are indeed pertinent to the aeronautical community.

Again, I will refer you to the statement in the record of yesterday's hearings. We will make certain that that is available to you.

As I said before, we will certainly be back in touch with the FAA to see how you follow through on this. I really believe that the public interest would require a re-examination of your position on this.

Let me recognize counsel for the minority again.

Mr. **Rheem**. I just wanted to thank the witnesses, and Dr. Reighard, and certainly say that at no point does the committee feel that the professionalism or the knowledge of the people involved doing your research was at any particular fault. We know that with the rapid changes that often occur in the status and development of research, that there is often a lag time before new results can be integrated into agency programs.

I believe what Mr. Skeen wanted to know—and hopes you would agree—is that you are open to new research results and that you are willing to take them into consideration in your research program at FAA.

Dr. **Reighard**. I want to reaffirm that it is the nature of FAA's business to keep abreast of anything that would relate to safety. We are always interested in anything that could be reasonably done to improve safety. You can be assured that we professionally in the biomedical community in FAA feel the same way.

Mr. **Gore**. I welcome that statement. I associate myself, as chairman, with the remarks made by minority counsel. I think they are most appropriate.

A couple other quick questions. When the FAA was contemplating changes in the flight time-duty time regulations for pilots, was your office consulted?

Dr. **Reighard**. I do not recall formally and officially coordinating the rulemaking in its final form. Of course, at various times over the years members of my staff have discussed matters such as fatigue and so on with the operating personnel, who were the persons who prepared that rulemaking.

Mr. **Gore**. But you were not consulted with respect to the pending changes in flight time-duty time regulations?

Dr. **Reighard**. I indicated that I did not officially coordinate nor was my coordination sought with regard to the final form of the notice of proposed rulemaking.

Mr. **Gore**. If the public interest is to be protected, it seems to me that these factors should be taken into account and the Federal Air Surgeon should be consulted, instead of just leaving the whole thing up to the airlines to suit the economics of the situation.

Do you currently have research underway or contemplated on performance decrement due to circadian dysrhythmia or desynchronosis?

Dr. **Reighard**. No, we don't. We are, however, aware of the work that is funded by the Federal Government that is ongoing at NASA-Ames.

Mr. **Gore**. As I said before, we will be back in touch with you. We will look forward to working with you.

I would like to thank the witnesses from the NRC and the FAA for being on the concluding panel. We will endeavor to prepare a useful report which collates the information which has been provided during these hearings from various points of view. We may well have some formal recommendations for the FAA and NRC in that report.

Let me simply close by thanking all of our witnesses who have contributed to these hearings. We appreciate it very much.

The hearing stands adjourned.

[Whereupon, at 1 p.m., the subcommittee adjourned.]

# APPENDIX A

## STATEMENT OF DR. TIMOTHY H. MONK
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# EUROPEAN SHIFTWORK RESEARCH

## Unsolicited evidence to the Congressional Committee[1]

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## SHIFTWORK AS A POTENTIAL STRESSOR

The rapid growth in shiftwork over the last few decades has meant that society can no longer rely upon a small pool of people who happen to be able to cope happily with shiftwork. In both Europe and the United States it has been estimated that more than 20 percent of the work-force is currently engaged in some sort of shift system. Thus, it has become necessary to find out more about shiftwork and shiftworkers, so that any detrimental effects on people who are unable to cope with shiftwork can be ameliorated. In Europe, in particular, this has resulted in quite a substantial body of research. That research will be outlined here. There is a clear need for equivalent research to be carried out in North America, and one aim of the Institute of Chronobiology is to go some way towards filling that need.

For the worker to successfully cope with shiftwork there are essentially three factors which have to be "got right", namely sleep, social and family life, and circadian rhythms. All three are interrelated, such that a failure in any one of them can negate any positive effect accrued from success with the other two. Sleep forms the major preoccupation in the life of many shiftworkers. On average, rotating shiftworkers get about seven hours less sleep per week than their dayworking counterparts (Bjerner and Swensson, 1953). Very often the patterning of work, leisure, and sleep is changed by the shiftworker on nightshift so that sleep is taken straight after work rather than after a period of recreation. This has the advantage of allowing the early evening to remain free for recreation, and allows the attitude that one might simply have been rather late in getting to bed, i.e. the experience of a delay in the sleep/wake cycle, rather than a complete inversion of it. It does mean, however, that for any further lateness in going to bed the likelihood of a good day's sleep can be quite dramatically reduced.

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[1] This evidence comprises an almost verbatim transcript of much of the material presented in a chapter by T.H. Monk and S.Folkard entitled "Circadian Rhythms and Shiftwork" published in the book "Stress and Fatigue in Human Performance" edited by G.R.J. Hockey, and published in 1983 by John Wiley and Sons Ltd, Chichester. This material is thus not for publication, and all rights are reserved by the authors and publisher. ©1983 John Wiley & Sons Ltd.

This introduces the second factor which is that of the social problems inherent in night-work. In most households, mornings are basically rather noisy times. Social tensions and strains for the shiftworker can often thus occur simply as a product of the night-worker's need for peace and quiet conflicting with his wife's need to run a family household. Parenthetically, the female shiftworker is very often expected to perform household management duties as well as her work, and for her the "sleep debt" can become quite enormous. Other social problems accrue from evening working which very often precludes enjoyment of television, theaters and clubs. The negative effects of these social problems have been catalogued by a variety of authors (reviewed by Walker, 1978).

The third factor, that of circadian rhythms and their adjustment (or rather the lack of it) has dominated much of the recent research in the shiftwork area. That a circadian structure exists is obvious, with dramatic differences in behavior and physiology between the states of sleep and wakefulness, and an overwhelming preponderance of sleep during the hours of darkness. What is less obvious is the complex pattern of gradual physiological and psychological changes that underlie this cycling of sleep and wakefulness, and the degree to which this pattern is self-sustaining and internal to the organism. Only when these more subtle factors are understood can the problems of the shiftworker be properly tackled.

## Shift systems

From our knowledge of circadian rhythms it is clear that the pattern with which morning, evening, and night-shifts are worked is important in two respects. First, the rate with which shifts change will determine the degree of circadian rhythm phase adjustment that can occur, with little or no phase adjustment occurring when only one or two shifts of a particular type are worked before changing to a different type. Secondly, the direction of rotation would also seem to be important. Although there is little direct evidence in this respect, the fact that endogenous rhythms tend to be longer than 24 hours, together with data from the jet-lag area, suggests that rotation in the order morning, evening, night might facilitate adjustment rather better than the direction night, evening, morning, since the latter requires a phase advance, or shortening, of the circadian rhythm. (See Wever, 1979, though for a critical discussion of this issue).

Although there are many different types of shift system it is possible to create three broad categories. The first category comprises "permanent" shift systems, where any one individual only ever works one sort of shift. The classic example of this is the night-watchman whose job is only there during the hours of darkness. Other examples are office cleaners, who work either evenings or very early in the morning, and night nurses. Recently in Europe there has also been a growth in the "twilight" shift, where housewives are encouraged to come into a factory between about 5.0 p.m. and 9.0 p.m. while their husbands look after the children.

At the other end of the scale is the category known as "rapidly rotating" shifts. Under this type of system the worker never has more than one or two shifts in a row, before changing to a different time. Thus, he might work two morning-shifts, followed by two evening-shifts, followed by two night-shifts, followed by two or three days off, the cycle then repeating itself. This type of shift system is particularly popular in Europe, and is referred to as the "Continental" or "Metropolitan" system.

In between the permanent and rapidly rotating shift systems are the slowly (i.e. weekly, semi-monthly, or monthly) rotating methods. This type of shift system is probably the one used most frequently, particularly when the system is not continuous (i.e. when there are times or days when there is no one working); it is particularly prevalent in Britain (and indeed in North America).

## Circadian rhythms and work efficiency

Just as there are circadian rhythms in physiological measures, so also are there circadian rhythms in performance efficiency. The present section will present a summary of the major results in order to provide a basis for discussing performance changes during adjustment to shiftwork.

Following the work of Kleitman (1939, revised 1963) and Colquhoun (1971) and his associates, it has become accepted that for many tasks there is a strong parallelism between the circadian rhythms of temperature and performance. Thus, performance at these tasks is held to show a steep rise from early to mid-morning, a more gradual rise to an evening peak (perhaps interrupted by a post-lunch dip), followed by a sharp decline into the hours of sleep. Tasks in which such a pattern is particularly clear are visual scanning tasks in which the subject is required to work his way through visual material, finding and indicating targets (Monk, 1979). However, in contrast to such tasks, those that are more complex, and involve a high working memory load show a very different time-of-day trend. Thus, for example, performance at a task measuring immediate memory for material presented in prose shows a decline over the waking day, with a trough in the early evening (Folkard and Monk, 1980). Thus any explanation of circadian performance rhythms has to account not only for the the rhythms themselves, but also for the differences in time-of-day functions that are observed for different tasks.

An elegant demonstration of the breakdown of the parallelism between performance and temperature rhythms with increased memory load has been provided by Folkard, Knauth, Monk, and Rutenfranz (1976); see Figure 1. Thus, from an applied point of view it is clear that to ascertain the times of best and worst performance one must take into account the components of the task that the worker is being asked to perform. It would, moreover, appear that the memory load of the task might be an important index in that respect, although even within the broad field of memory the difference between short and long-term memory is important.

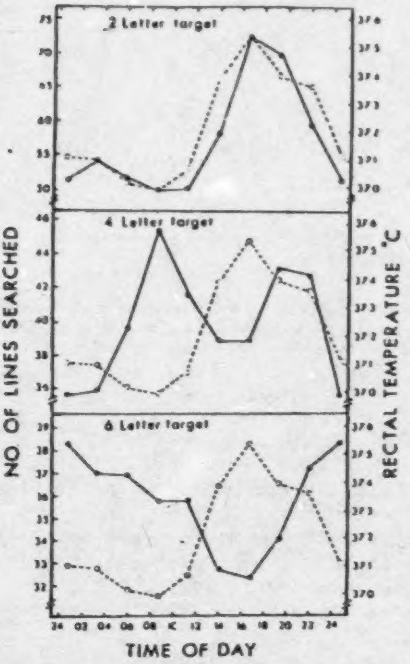

Figure 1 The circadian rhythm of two subjects' performance on low (two letter), medium (four letter) and high (six letter) memory load versions of a visual search task ( ●———● ), together with that in rectal temperature (○------○). From Folkard and Monk (1979). (Reproduced by permission of the Human Factors Society Inc.)

## Physiological aspects of adjustment

If one requires people to work at night then either (a) their circadian systems will adjust to become "in tune" with the new schedule, or (b) they will be required to work and sleep at times that are inappropriate relative to the phase of their circadian rhythms. Problems arise because the process of adjustment takes a considerable amount of time. Thus, for example, it was found that for two subjects in a laboratory shiftwork study (Monk, Knauth, Folkard, and Rutenfranz, 1978) up to 12 days had to elapse before the phase (time of peak) of their rectal temperature rhythms had shifted to be fully in phase with the new routine (Figure 2).

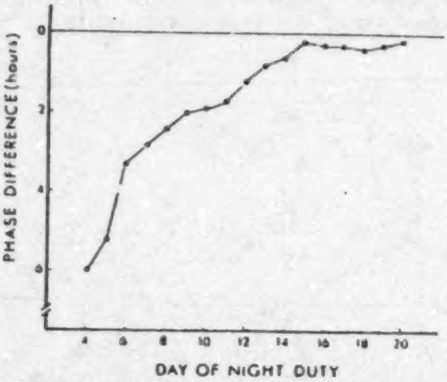

Figure 2. The phase adjustment curve (number of hours that rhythm is 'out of phase' with new routine) for the circadian rectal temperature rhythm of two subjects working 21 consecutive night shifts. After Monk *et al.* (1978).

Because this process of adjustment does take so long, expert European opinion is divided into two opposing views. In one group are those who hold the view that the primary goal should be one of encouraging adjustment, and that permanent shift systems should thus be favored, with the shiftworker being encouraged (by the provision of special housing and recreational facilities, for example) to maintain that schedule even on his days off. The latter point is important, since although there is evidence that adjustment to night-work may be facilitated in experienced night-workers (Folkard, Monk, and Lobban, 1978), the strength of the zeitgeber favoring a day-oriented schedule can result in very rapid loss of nocturnal orientation in circadian rhythms (Van Loon, 1963). The advantages of a permanent form of shift system are that the night-shift efficiency would then be comparable to that of the day-shift, and that the night-worker's sleep would be no worse than that of the dayworker.

In the other group are those who maintain that although desirable from a strictly circadian point of view, perfect adjustment is in most cases impossible to attain. They argue that only in very extreme cases such as the Arctic Circle or politically totalitarian regimes, can the commitment to a nocturnal way of life be absolute. These experts would thus favor the use of rapidly rotating shift systems, where long runs of duty on a particular shift are specifically avoided. In such situations the circadian rhythms remain effectively diurnal (day-oriented) with some flattering, but little or no shifting of phase (see, for example, Figure 3). They consider such a lack of adjustment to be a positive advantage since they believe that the process of repeatedly re-entraining (or resetting) the circadian system is potentially more harmful than that of living, for a few days at a time, with a circadian system that is at an entirely inappropriate phase. The disadvantages of a rapidly rotating system are (a) that night-shift performance may be impaired (but see later section), and (b) that a sleep debt may quickly build up, requiring that two or three days off are given after each (short) run of night duty (Rutenfranz et al., 1977).

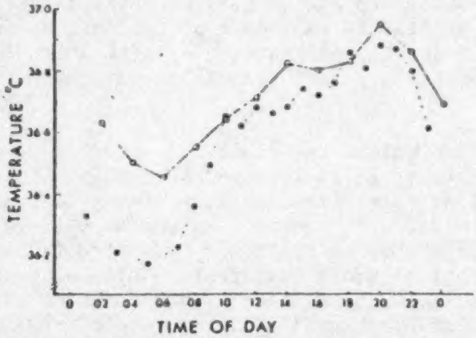

Figure 3 Circadian oral temperature rhythm (○———○) of six subjects working in a rapidly rotating 12-hour shift system, with either three or four 24-hour cycles from each subject. After Monk and Embrey (1981). A 'standard' oral temperature rhythm from 73 diurnal subjects is also included for comparison ( ●———● ). After Colquhoun (1971). (Reproduced by permission of Pergamon Press Ltd.)

Inevitably, with such a difference between these two positions, there are strong arguments in favor and against both viewpoints. However, both "camps" would undoubtedly agree that weekly rotating shift systems are undesirable from almost all points of view. Such systems suffer from the disadvantage of both rapidly rotating and permanent shift systems, without attracting the benefits of either of them. Thus, they involve a sufficient number of night-shifts for the worker's circadian rhythms to be come disrupted, but an insufficient number for them to become adjusted to the change in the sleep/wake cycle.

## Fatigue and sleep loss

Whatever the specific cause, the main side-effects of shiftwork that are apparent to the worker himself are those of fatigue and sleep loss. As mentioned earlier, sleep becomes a major preoccupation of the shiftworker, and it is possible to make generalizations about the amount of sleep taken by day and at night, with about 2 hours less sleep in the former than in the latter (Rutenfranz et al., 1977).

It is not only the night-shift, however, that creates problems of sleep duration. Knauth, et al. (1980) studied the duration of sleep associated with various shifts and combinations of shifts. Even when sleep was taken at night, these authors found that because of the time needed to travel to work, etc. significantly less sleep was taken before a morning shift. Thus, problems can arise even for the shiftworker who is on a "double day" shift system, alternating between "morning," (e.g. 0600 to 1400) and "evening" (e.g. 1400 to 2200) shifts. This emphasizes the need for care in the choice of "changeover" times, for even a 0600 start will probably require the worker to set his alarm clock for 0500. The problem is one of balancing the desire for an early finish to both shifts (so that more of the afternoon is "free" for the morning shift, and that the evening shift can get to bed on time) with that for a more reasonable starting time in the early morning.

Although sleep (or rather the lack of it) is undoubtedly an important contributory factor to the problem of shiftwork, one must be careful to recognize that it is very often more of a symptom than a cause. It can be tempting to believe that if only the night-worker's bedroom could be soundproofed sufficiently, then all his problems would disappear. This, however, is not the case, as was indicated by a study of night nurses carried out by Folkard, Monk, and Lobban (1979). In developing a questionnaire to predict suitability for shiftwork they found a factor $R_s$ (rigidity of sleeping habits) to be an important (negative) predictor of circadian adjustment. Interestingly, high $R_s$ types also reported their day-sleeps to be more disturbed by noise of various types than did low $R_s$ types (i.e. flexible sleepers). Since the housing conditions of the two groups were essentially the same, one might conclude that having one's day-sleeps disturbed by noise is as likely to be a result of shiftwork adjustment problems as a cause of them.

## SHIFTWORK AND PERFORMANCE

### Laboratory studies

Because of the difficulties involved in obtaining permission to carry out studies, the irregularity of many shift systems, and possible contamination by a variety of factors, much European research on shiftwork performance has taken place in the laboratory. Most of these studies have used simple "immediate processing" and monitoring tasks to assess performance efficiency and have used subjects who lack shiftwork experience. The basic finding in these "experimental" shiftwork investigations has been that the circadian rhythm in performance efficiency adjusts rather slowly and, like the temperature rhythm (Figure 3), takes at least twelve successive nights before becoming completely adjusted to the new schedule (Colquhoun, Blake, and Edwards, 1968a, 1968b, 1969; Knauth and Rutenfranz, 1976). Thus, the parallelism between temperature and performance on this type of task has been found to persist even under these unusual conditions.

From these results, it has been argued the adjustment of circadian rhythms should be beneficial to night-shift performance since it would result in higher temperatures and hence better performance (see Colquhoun, 1971). In view of this, the best shift system for maintaining high levels of productivity and safety for this type of task has been argued to be a permanent one in which the night-workers are persuaded to remain on a nocturnal routine on their rest days. Although such a measure is rather extreme, there are situations, such as the control room of a chemical plant or nuclear reactor, where the potential cost to society of an accident is high enough to warrant it.

However, this recommendation does not apply when the night-worker's task involves a working memory load. As we have already seen (in Figure 1, for example), the parallelism between temperature and performance does not hold for such tasks. Indeed, there is a negative relationship between temperature and the performance of tasks with a high working memory load. This means that performance on this type of task should actually be rather good on the night-shift, provided there was no disruption, or adjustment, of the shiftworker's circadian rhythms (Folkard et al., 1976; Folkard and Monk, 1979).

European laboratory studies have also been used to investigate the rate with which different circadian performance rhythms adjust their phase to the new schedule. Monk, Knauth, Folkard, and Rutenfranz (1978) studied the phase adjustment of low (2-MAST) memory load visual search performance to 21 consecutive night-shifts. From Figure 4 it is clear that there were marked differences in rate of adjustment between different versions of the test, with the phase of the low memory load version adjusting at the same rate as that of rectal temperature, whilst that of the high memory load version adjusts considerably faster. This confirmed an earlier finding from a field study by Hughes and Folkard (1976) discussed in a later section.

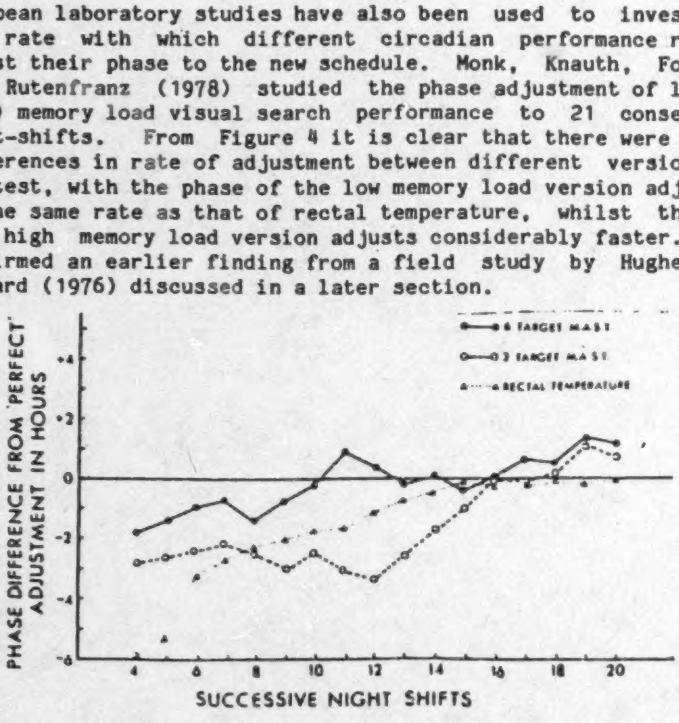

Fig. 1

From these laboratory studies one is thus left with the conclusion that simple (low memory load) performance will tend to parallel the temperature rhythm, adjusting rather slowly, and generally indicating poor night-shift performance. However, for complex (high memory load) tasks, laboratory studies suggest the counterintuitive prediction, that night-shift performance will initially be better than day-shift performance, with phase adjustment actually being harmful to the former. They also suggest that such a phase adjustment would be rather more rapid than that of the temperature rhythm.

## Field studies

There are remarkably few field studies of actual shiftwork performance. In fact, until very recently there appeared to have been only six published studies that report relatively continuous, 24-hour "real-life" performance measures. Nevertheless, from Figure 5 it is clear that there is a fair agreement among these studies that an impairment of performance occurs during the night shift. Thus, performance on the night-shift was found to be slower both in answering a switchboard (Browne, 1949) and in tying threads (Wojtczak-Jaroszowa and Pawlowska-Skyba, 1967), and less accurate in reading meters (Bjerner and Swensson, 1953). There was also some evidence that a decrease in alertness at night might cause accidents to be more frequent then (Prokop and Prokop, 1955; Hildebrandt, Rohmert, and Rutenfranz, 1974; Folkard, Monk, and Lobban, 1978). However, the "real-life" nature of these studies has meant that it has been extremely difficult to control for possible "contamination" by other factors. This point is illustrated by the study of Meers (1975) who found clear evidence of lower production quality on a night-shift, but also found that this might be attributable to poorer maintenance of the machine involved.

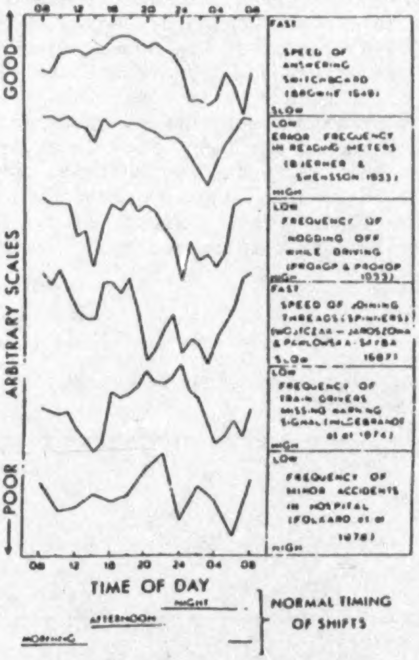

Fig 5

It would seem, therefore, that for simple processing and monitoring tasks the laboratory findings have been confirmed with predominantly inferior performance on the night-shift. More interesting from a theoretical point of view is the test of the laboratory prediction that high memory loaded performance would be better performed at night than during the day. This has recently been undertaken (Monk and Embrey, 1981) using process controllers in a large chemical plant. These controllers had a high memory loaded job, entering coded information into the computer which controlled the plant. They worked a rapidly rotating 12-hour shift system and their circadian rhythms appeared to remain effectively diurnal (see Figure 3 above). For a period of about a month, every error made by the controller was automatically logged by the computer. The resultant time-of-day function is plotted in Figure 6. From this function it is clear that the best performance (fewest errors) occurred on the night-shift, an effect which appears not be to due to any difference in workload.

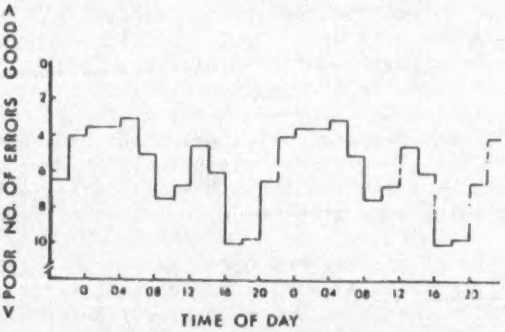

Figure 6 The circadian rhythm of 'on-job' performance taken from ten process controllers over a month's period. Improvements in performance (fewer errors) are represented by a rise. Two cycles of the 12 values defining the rhythm have been plotted. After Monk and Embrey (1981). (Reproduced by permission of Pergamon Press Ltd.).

This finding is in line with the results of an earlier study which indicated that night nurses' immediate recall for training material is better following 0400 presentation than following 2030 presentation (Monk and Folkard, 1978; Folkard and Monk, 1980).

In sum, although real-life shiftwork performance will often be lowest on the night-shift, the reason for this would appear to be dependent upon the type of task the shiftworker has to perform. For simple immediate processing tasks it may be low because of the lack of adjustment of the shiftworker's circadian rhythms. Thus, for these tasks permanent shift systems may prove to be optimal. However, for more complex working memory tasks, performance may be poor because of the more rapid adjustment that in this case lowers efficiency. For this latter type of task very rapidly rotating shift systems that minimize the disruption of the shiftworker's circadian rhythms may well be preferable.

## OTHER FACTORS IN SHIFTWORK

### Individual differences

Even the most cursory investigation of shiftworkers "in the field" reveals wide ranging individual differences, with some shiftworkers experiencing no problems at all, and others leading miserable lives, barely able to cope. There is thus an obvious benefit to be gained if some instrument can be developed to differentiate between the two types before they actually get themselves involved in and committed to shiftwork.

One technique used in Europe has been to study the individual characteristics that are known to affect normal circadian rhythms. The most popular of these variables, "morningness" (whether one is a "lark" or an "owl") and extroversion. In general, the circadian rhythms of evening types and of extroverts (especially those scoring high on neuroticism) have been found to adjust more rapidly than those of morning types or introverts (see Akerstedt and Froberg, 1976; Colquhoun and Folkard, 1978). (Also, since shiftworkers often "sleep-in late" during the morning, one might expect evening types to cope better with shiftwork simply through being more able to do this than morning types.)

Another technique of enquiry has been to develop a purpose-built questionnaire specifically designed to predict shiftwork suitability. The "Circadian Type Questionnaire" (Folkard, Monk, and Lobban, 1979) produces three factors, namely rigidity of sleeping habits (Rigid Sleeper $R_s$ versus Flexible Sleepers $F_s$); vigour (Vigorous V versus Languid L types; and morningness (Morning M versus Evening E types). The first two of these factors have been found to predict both differences in rate of physiological adjustment in night nurses, and differences in rate of sleep/wake cycle adjustment to a spring Daylight Savings Time change (Folkard, Monk, and Lobban, 1979; Monk and Aplin, 1980). This line of research thus appears to be a promising one, although considerable development is clearly needed.

One fundamental problem with this whole general approach is that, as we have already seen, it is unclear whether the adjustment of circadian rhythms is desirable or undesirable. To some extent, the answer to this may depend on the type of task the shiftworker has to perform but we also need to consider the shiftworker's health and social problems. Here again, opinion is divided between those who feel that the adjustment of circadian rhythms will minimize these problems, and those who argue that the maintenance of normal, day-oriented, circadian rhythms is better in this respect. Thus, for example, Reinberg et al. (1980) have recently shown normal rhythm amplitude to be inversely related to phase shift in shiftworkers, with a faster rate of phase adjustment (of the temperature rhythm) occurring in people whose normal (diurnal) rhythms exhibited a smaller natural amplitude. However, the group with the largest phase shift was the one least happy with shiftwork. Thus, for many the trouble with shiftwork may be that their circadian rhythms do readily adjust. This is highlighted by a recent study by Folkard and Monk (1981a) of computer operators on a weekly rotating shift system. Only one operator complained that he had problems coping with shiftwork, commenting that: "I find shiftwork to be very unnatural and will soon be giving it up as it is having an adverse effect on my health --mainly tension and nervousness." Despite this, his circadian rhythm in body temperature showed virtually perfect adjustment to his shift system.

Such findings do suggest that there may be certain situations and/or individuals for which the adjustment of circadian rhythms is undesirable. They thus highlight the fact that although there is considerable evidence on individual differences in the adjustment of circadian rhythms, this evidence cannot be used to make practical recommendations until we have determined whether or not such adjustment is to be encouraged.

A second fundamental question is that of whether circadian factors are so far outweighed by other factors as to be largely irrelevant to the question of shiftwork performance, it is pointless to pontificate about day-sleeps and circadian rhythm adjustment if the night-worker is also trying to hold down a second job during the day ("moonlighting"), or is expected to look after a house and family as soon as she gets home from work in the morning. Thus, the major individual difference in shiftwork adjustment must be that of level of commitment (Folkard, Monk, and Lobban, 1978). Without a high level of commitment to the required routine, it may be largely irrelevant whether one is an extrovert or introvert, lark or owl.

## Medical and social considerations

A number of European studies have looked at the effects of shiftwork on health, and these have recently been reviewed by Harrington (1978). There appears to be no good evidence of reduced life expectancy in shiftworkers (Taylor and Pocock, 1972), or, on balance, of increased absence due to sickness (Harrington, 1978). Indeed, the only reliable detrimental effect of shiftwork on health would appear to be an increase in gastro-intestinal symptoms and diseases.

Other medical considerations relate to certain diseases or conditions which might indicate that a person should try to avoid shiftwork. Thus, for example, a diabetic shiftworker might have problems in balancing his sugar and insulin levels, and an epileptic shiftworker might find that his seizures increase in frequency due to the resultant sleep loss (Rutenfranz et al., 1977). Also, the link between shiftwork and gastro-intestinal complaints would suggest that people with a tendency towards problems in that area should also try to avoid shiftwork. Generally with respect to health, shiftwork is probably best conceived as a stressor which may have little or no impact on the young, healthy individual, but which can dramatically aggravate otherwise minor complaints due to ill-health or increased age. Thus, in a recent survey of oil refinery workers, Koller et al. (1978) found that only 18.5 percent of the shiftworkers believed that they would be able to continue with that kind of work until retirement.

The disruption of a shiftworker's social and family life is one of the most frequent sources of complaint and has been mentioned earlier. However, studies of shiftworkers' attitudes to different systems have produced somewhat conflicting findings. These studies have been reviewed in detail by Walker (1978). In general, shiftwork is disliked by those undertaking it, although there are some individuals who positively like it. This latter finding may explain the tendency for the early studies in this area to have found "permanent" systems more acceptable, while the more recent studies have tended to obtain results favouring rapidly rotating shift systems. The incidence of shiftwork has doubled over the last 25 years (Walker, 1978) and it thus seems possible that in the past there were sufficient people who liked night-work to man permanent night-shifts. However, with the increased incidence of night-work it would seem that we no longer have sufficient numbers of such people, and thus have to employ people to work at night who dislike doing so.

The question as to the optimal form of shift system from a social point of view is thus not a simple one. Nevertheless, as Walker (1978) points out, in Europe an increasing number of firms are adopting rapidly rotating shift systems, often as a direct result of pressure from the shiftworkers. The advantage of such systems is that about 75 percent of sleeps can be taken at the "normal" time, and that in general 75 percent of the shiftworker's life can be oriented to a normal diurnal pattern of life. Indeed, Wedderburn (1967) suggests that "swiftly rotating systems may have hit on an optimum solution for both the physiological and social needs of man". What is needed is an equivalent series of research to ascertain whether such a system would be equally desirable in North America.

## CONCLUSIONS AND PRACTICAL IMPLICATIONS

From the study of circadian rhythms in general, it would appear that such rhythms: (a) are often primarily endogenous, i.e. internal to the organism and self-sustaining; (b) are controlled by a variety of physical and social time cues (zeitgeber); and (c) often have a natural periodicity that is slightly greater than 24 hours. Thus, in practical terms one should bear in mind: (a) that such rhythms can take a long time (e.g. up to two weeks) to adjust; (b) that such adjustment can be helped along by the right zeitgeber (e.g. by making the shiftworker's environment less obviously day-oriented); and (c) that in a rotating shift system a shiftworker will probably find it more easy to stretch his rhythms (on a mornings-afternoons-nights schedule) than to shrink them (on a nights-afternoons-mornings schedule). Also, the suggestion that there are two groups of oscillators (clocks), one controlling the sleep/wake cycle the other the temperature rhythm, means that to have succeeded in adjusting the sleep/wake cycle does not necessarily imply that all the shiftworker's body clocks have been so re-set.

From the study of circadian performance rhythms one can conclude that it is wrong to make generalizations about the "best form of shift system" for work efficiency, without taking into account the nature of the task to be performed. As with physiological circadian rhythms, a multi-oscillator approach would seem to be needed. Task differences in both normal diurnal rhythm and rate of phase adjustment suggest that a distinction should be made between simple repetitive or monitoring tasks and complex memory-loaded cognitive tasks. For the former, a permanent system would seem to be preferable, with the maximum possible phase adjustment. For the latter, adjustment should be discouraged by using rapidly rotating shift systems whenever possible. However, from this and many other points of view, the weekly rotating shift system, should be avoided.

From the study of individual differences one might conclude that extroverts and/or evening types might show the most rapid phase adjustment, although one should remember that that might not always be an advantage. Also, it should be remembered that level of commitment is probably the most important individual difference.

European studies of sleep, health, and social problems point to shiftwork as a stressor which can exacerbate any existing problems which had hitherto been minor. The problem of inferior day-sleeps should not be ignored, and wherever possible a number of recuperative rest days should follow each run of night-duty. Health problems appear to be mainly gastro-intestinal and might be, at least partially, alleviated by the provision of adequate canteen facilities for the shiftworker. Social problems are the hardest to quantify and pin-down, and it is often tempting to either dismiss them as peripheral, or trivialize them. They are, however, crucial to the shiftworker's health, well-being, and efficiency. In living with shiftwork he is already suffering (to a greater or lesser extent) from one stressor; to burden him with the additional one of social and family problems is to court emotional disaster.

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